Hydrologic and Geomorphic Considerations for Silvicultural Investments on the Lower Skeena River Floodplain

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SUMMARY

This report evaluates four inter-related components essential for silvicultural planning on the lower Skeena River floodplain: biophysical information, erosion potential, flooding characteristics and environmental fate of herbicides. These components are detailed so the approach can be applied in other floodplain areas.

Detailed biophysical data of direct relevance to forest management on the Skeena River floodplain are presented. These data include: 1) the annual groundwater regime and its driving forces; 2) the stratigraphy of the alluvial deposits; 3) the physical characteristics of the soil; and 4) the climatic regime of both the air and soil.

The evaluation of floodplain stability and island longevity is based on a chronological sequence of maps. A total of five air photograph series, spanning 40 years, are used to calculate erosion and deposition rates. These rates are ranked according to a five-class system ranging from no change historically to large annual channel changes. Maps are presented to show: 1) historical channel shifts, and 2) floodplain and island stability. These maps are used to determine the long-term management suitability of the Skeena River. The most important factors controlling erosion are flood flows, sediment sources and specific morphological features.

The survival and growth of Sitka spruce (*Picea sitchensis*) are related to frequency, duration and depth of flooding. Certain topographical and morphological features of floodplains are associated with these flood characteristics and are used to identify sites that will be unfavourable for establishment and growth of Sitka spruce. The method developed uses 1:10 000 scale air photographs and a five-category frequency/duration classification to identify site specific flooding potential. Ground elevation is critical in determining flood frequency, but terrain features control flood duration.

From the biophysical data and information on the nature of forestry herbicides, inferences are drawn about the probable environmental fate of herbicides on these floodplains, and recommendations are made.

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1 INTRODUCTION

Coastal floodplains are among the most productive ecosystems in British Columbia (Roemer *et al.* 1988). Many of these floodplains have the potential for supporting valuable climax stands of Sitka spruce (*Picea sitchensis*) and western hemlock (*Tsuga heterophylla*). On many larger river systems, however, such as the Skeena River, unsuccessful silvicultural treatments have left a legacy of unmerchantable stands of red alder (*Alnus rubra*) and Sitka willow (*Salix sitchensis*). In many cases, it is desirable to rehabilitate these unmerchantable stands of alder and willow and return them to high value Sitka spruce and black cottonwood (*Populus balsamifera* spp. *trichocarpa*).

While these sites are valuable, they are inherently complex to manage because of: 1) the potential for severe vegetation competition; 2) the high value of their fish and wildlife habitat; 3) the potential for recreational conflicts; and 4) the problems with insects and disease. In addition to these difficulties, floodplains are often subjected to high rates of natural erosion and seasonal flooding. The lower Skeena floodplains, which are composed of mainland sections and numerous islands, are subject to all of these problems.

Several vegetation management concerns, over the hydrology and geomorphology of these floodplains have been expressed by foresters and forestry managers:

- What are the rates of erosion of the alluvial islands and what is their expected longevity?
- What are the effects of seasonal flooding on the establishment and growth of Sitka spruce?
- What would be the environmental fate of any forestry herbicides used on these floodplains?

Two independent studies were initiated to provide answers to these questions. The results of these studies are compiled in this one report. Each of Chapters 3, 4 and 5 describes a different floodplain process or condition which may substantially affect silvicultural investments. Each chapter was written to stand alone. Thus, after reading the Introduction and Chapter 2, the reader can choose to read only one, two, or all of the chapters.

The main product of these projects was a collection of sensitivity maps. To generate these maps, original methodologies were developed. These methodologies are the main focus of this report. The maps in Chapter 3 and the graphs in Chapter 4 serve simply as an example of the product. Because the methodologies are process-based, we believe that with some additional refinements they could be used for solving similar problems on other large fluvial systems like the Nass, the Homathko, and the Fraser rivers.

This report presents our findings to date. Additional work is required to streamline the methodologies of both mapping systems to produce simple keyed guides for quick and easy field reference.

2 ENVIRONMENTAL DESCRIPTION OF THE SKEENA FLOODPLAIN: CLIMATE, SOILS, HYDROLOGY

P.G. Beaudry

2.1 Introduction

The Skeena River drains an area of over 58 000 km^2 of west central British Columbia (Figure 2.1). Upstream of Terrace, the Skeena River has a relatively high channel gradient and in many areas is confined by steep bedrock walls. Downstream of Terrace the river widens and the gradients decrease substantially, favouring the deposition of sediment. The 75-km stretch of river between Terrace and Kwinitsa is a sediment depositional zone and is characterized by large alluvial deposits which form a succession of island and mainland floodplain.

Detailed biophysical descriptions of the lower Skeena River area are included in several other reports. The general hydrometric data are given in Hoos (1976) and geological and vegetation data are detailed in a report by B.C. Hydro (198). The environmental description of the Skeena River floodplain presented here is based on 4 years of field data collected at plots located at sites considered to be representative of the Skeena floodplain. For general information the reader is directed to the above references.

The plot work and sampling for the environmental description were concentrated on the floodplain located at the confluence of the Kasiks and Skeena rivers about 40 km west of Terrace in the CWHvm biogeoclimatic subzone (Pojar 1988) (Figure 2.2). The work included describing the local atmospheric and soil climate regimes, the streamflow and groundwater regimes, and the stratigraphy and soil physical characteristics of the alluvial deposits.

2.2 Methods

2.2.1 Local climate

An automated weather station was installed to measure: 1) snowmelt and precipitation rates; 2) air and soil temperatures; 3) water table fluctuations; 4) relative humidity; and 5) solar radiation. These data were collected hourly for 4 consecutive years (1985-1989). Soil moisture and soil temperature was recorded at 5, 10 and 15 cm below the surface at four other locations on the floodplain (Figure 2.3).

2.2.2 Tides

At the beginning of this project it was not clear how far upstream the tidal influence extended. To determine both the spatial extent and the magnitude of tides along the lower Skeena River, a series of staff gauges were installed and monitored during two large tides at flood flows. The staff gauges were located approximately 5 km apart and extended from the Khyex River upstream to the Exchamsiks River.

2.2.3 Soils

Eight standard soil pits were dug and 51 soil samples were collected for analysis of soil characteristics. Soilcon Laboratories Ltd. was contracted to determine the following soil properties: 1) % organic matter; 2) bulk density; 3) effective porosity; 4) particle density; 5) saturated hydraulic conductivity; 6) air entry tension; and 7) the volumetric water content at five tension levels.

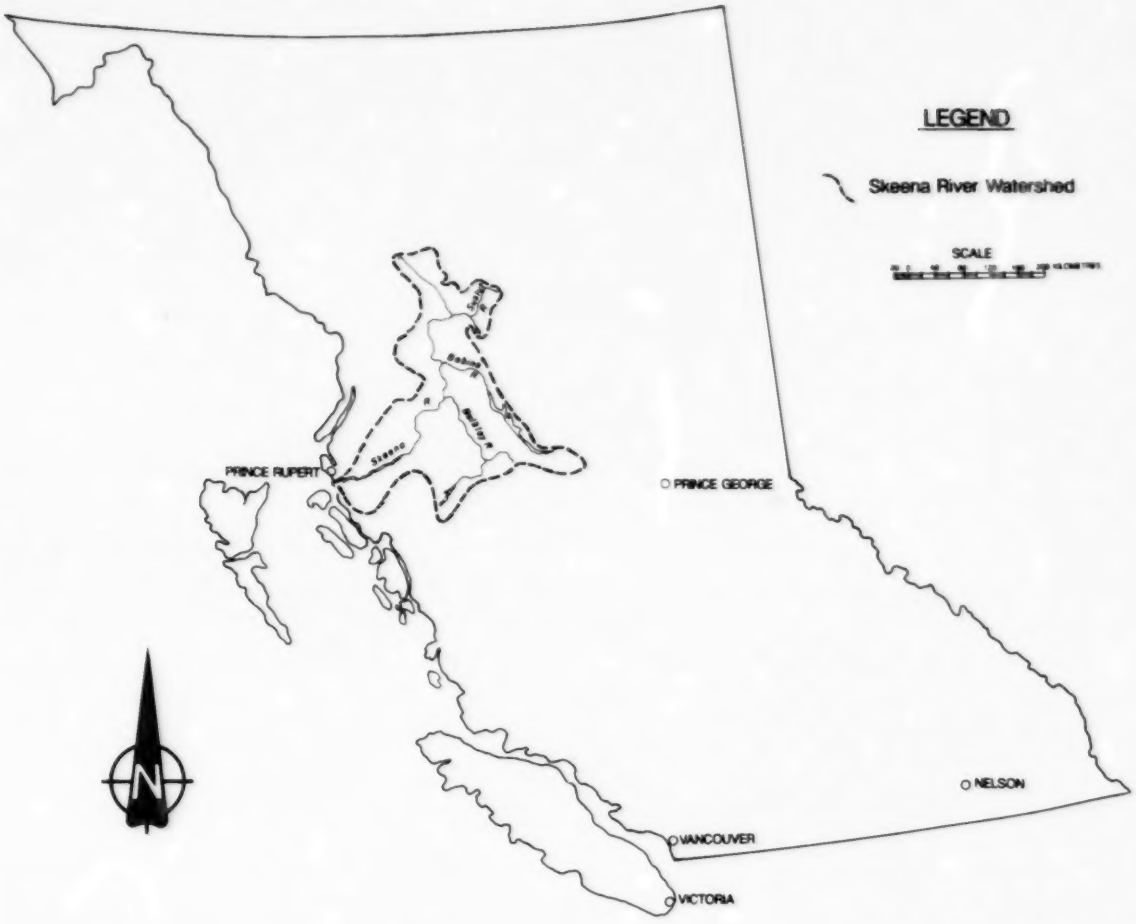

FIGURE 2.1. Skeena River watershed.

2.2.4 Stratigraphy

Sampling of surficial geology was conducted at two spatial scales to characterize the spatial textural variability and the stratigraphy of the alluvial deposits. At the intensive level, 30 samples were collected on grids 10 x 10 m. To cover the larger scale, samples were collected every 50 m along a 1110 m transect and a second 750 m long transect (Figure 2.3). The sampling was done using a 2.2 m long Oakfield soil sampler and all layers present in each core were recorded. The soils and the stratigraphy information were used to describe how water moves through the unsaturated soil.

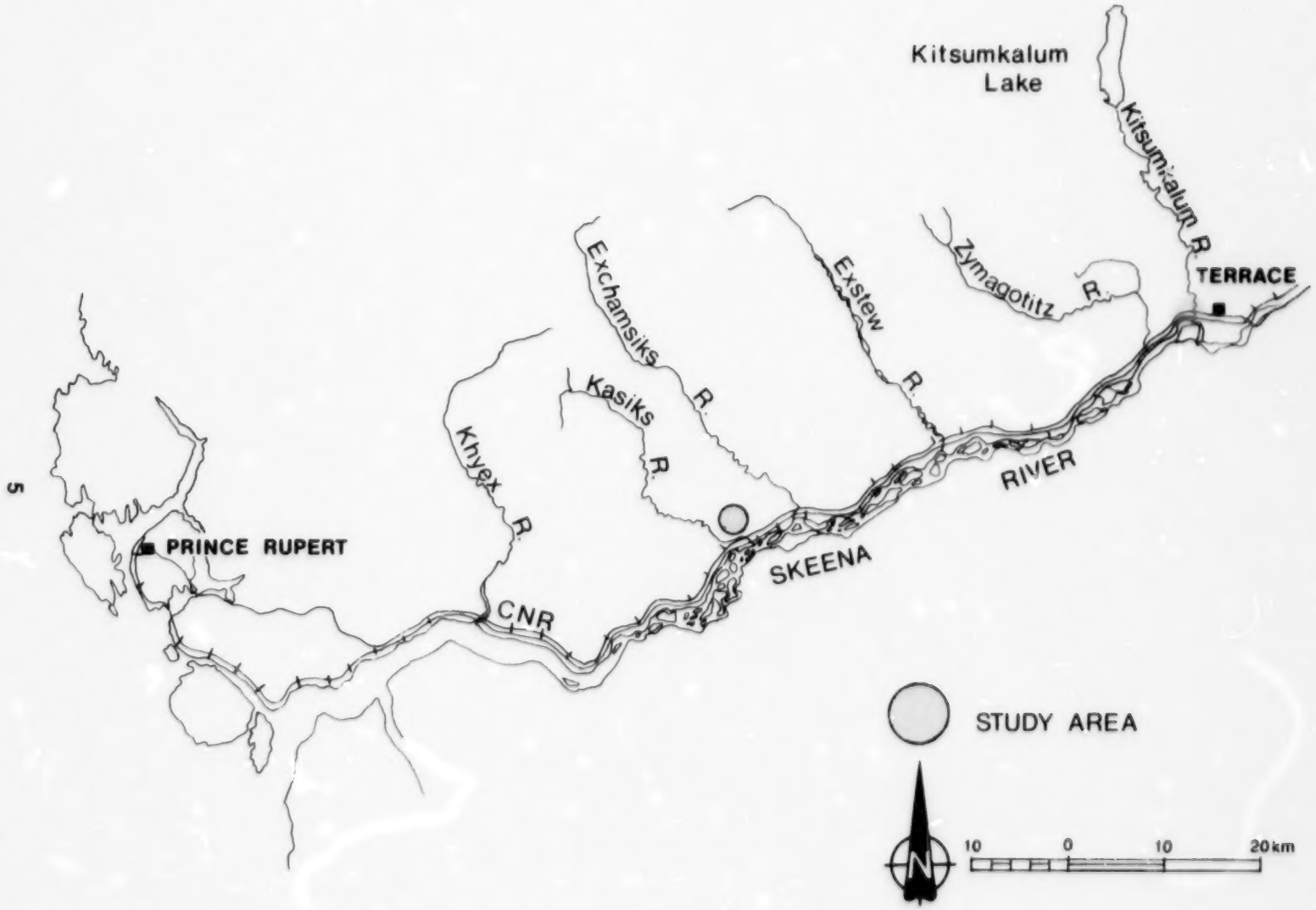

FIGURE 2.2. Location of study site.

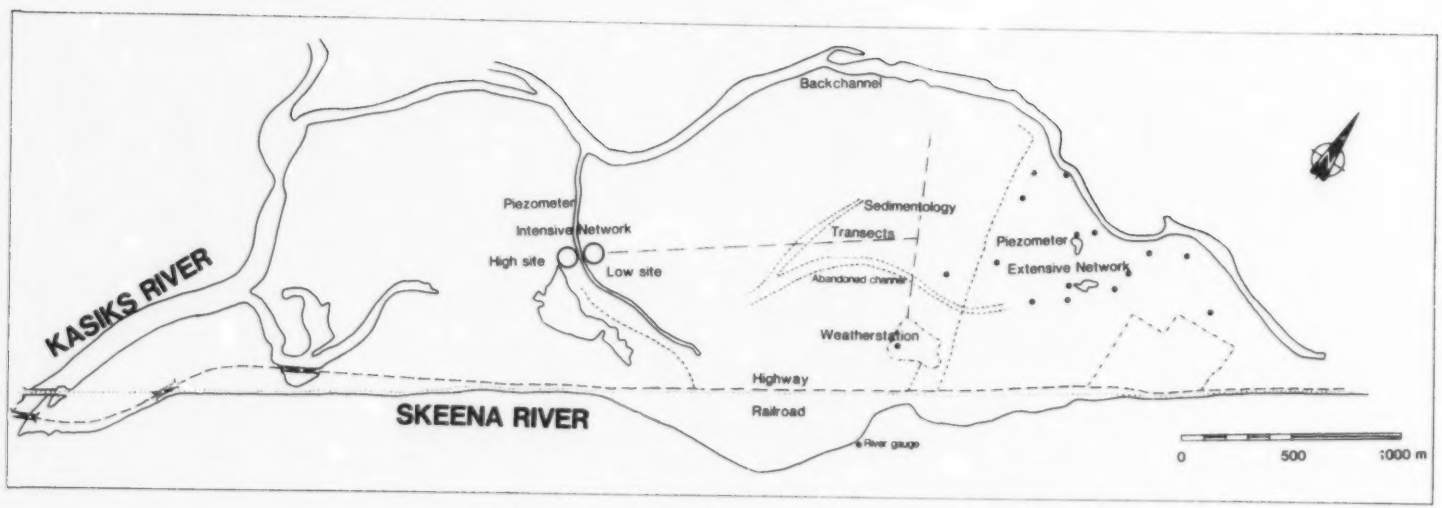

FIGURE 2.3. Location of piezometer networks, weather station, and sedimentology transects.

2.2.5 Groundwater regime

The groundwater regime was described using 58 groundwater wells[1] and piezometers[2] installed in numerous transects and networks. Forty of these were installed in an intensive network on both sides of an active backchannel, while 18 were installed in an extensive network which crossed the entire floodplain (Figure 2.3). The networks were designed to describe both localized and regional groundwater flow, and to provide us with an understanding of how water moves through the floodplain. In the intensive network, 12 piezometer nests were installed, each nest consisting of two or three piezometers. Within the nest, the piezometers were inserted to a depth of 1, 2, and 3 m (if depth to the gravel layer permitted it). The nests were designed to obtain information about both horizontal and vertical groundwater movement.

The wells and piezometers were read on a daily, bi-weekly, or monthly basis depending on the season and height of the groundwater. Four of the piezometers and the standpipe located in the Skeena River were equipped with a recording height gauge. The recorders yielded continuous measurements of water table and stage heights, providing accurate tracking of the relationship between river heights and groundwater regimes. A topographic survey was done to determine the relative heights of all the piezometers and wells and the ground surface where they were located. Pump tests were also performed in several of the piezometers to determine bulk hydraulic conductivities of the soil. A flow net analysis (Freeze and Cherry 1979) was used to determine the velocity and direction of groundwater movement at various times of the year.

2.3 Results and Discussion

2.3.1 Local climate

The lower Skeena valley is an area of relatively high annual precipitation. The average annual precipitation for the 3 years of measurement at the Salvus site was 1783 mm. The months with the lowest total precipitation are May, June, and July. The greatest monthly precipitation occurs in September, October, and November (Figure 2.4).

Air temperatures in the valley are quite mild as they are strongly influenced by the moist mild air that moves in from the coast up through the Skeena valley. Average monthly air temperatures range from a low of -4°C in January to a high of 17°C in June and July (Figure 2.5).

Because winter air temperatures are often close to 0°C, maximum depth of snowpack is extremely variable from year to year. The winter snowpack can be ephemeral–accumulating to a depth of 50-100 cm, quickly melting and accumulating again. Or, if the air temperature remains below 0°C throughout the winter, the snowpack can accumulate to depths of over 2.5 m.

2.3.2 Tides

Results from the June 15, 1987, tidal survey are shown in Figure 2.6. The tidal influence extends for about 30 km upstream of the Khyex River (just upstream of Polymar Creek). The tides alter the water surface elevation by 1 m at Kwinitsa River, 0.6 m at Kwinitsa East Creek, and 0.2 m at Polymar Creek. It is possible to predict both the upstream extent and magnitude of the tidal influence by combining the June and July data sets. For large tides during the spring runoff event, the tidal influence was calculated as: $T=3.6-0.12D$, where T is the maximum river water surface elevation change (m) due to tides and D is the distance in kilometres upstream of the Khyex River.

---

1 A groundwater well is a pipe with holes along its length, which measures the height of the water table.

2 A piezometer is a pipe with holes only at the bottom end, which measures the hydraulic pressure at a specific point in an aquifer. When it is used with other piezometers, a hydraulic gradient can be calculated and thus the direction of groundwater flow can be determined.

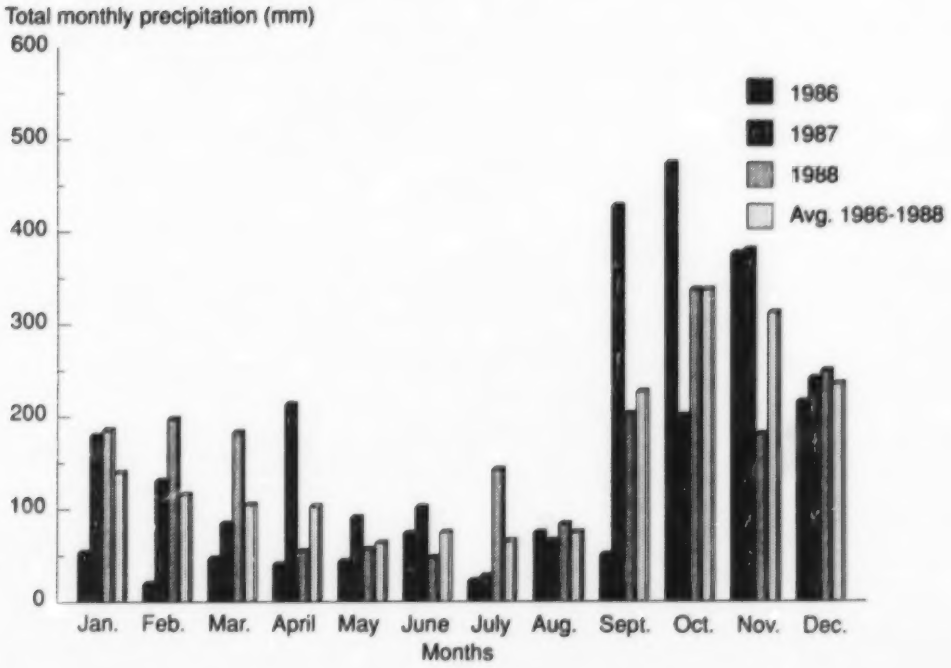

FIGURE 2.4. Annual precipitation regime at Salvus.

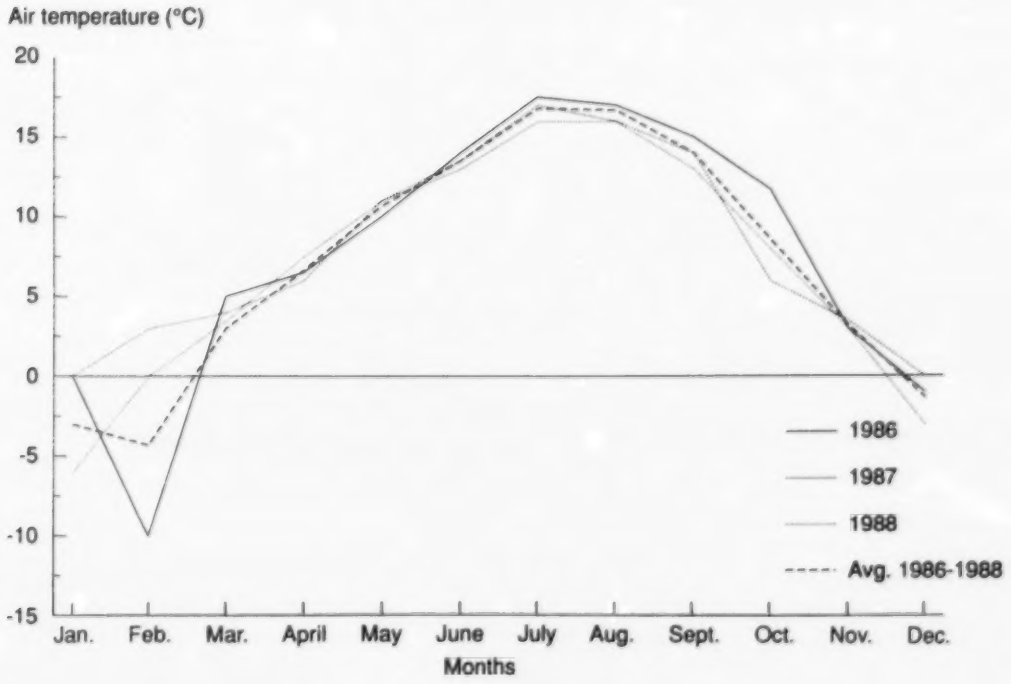

FIGURE 2.5. Mean monthly air temperatures at Salvus.

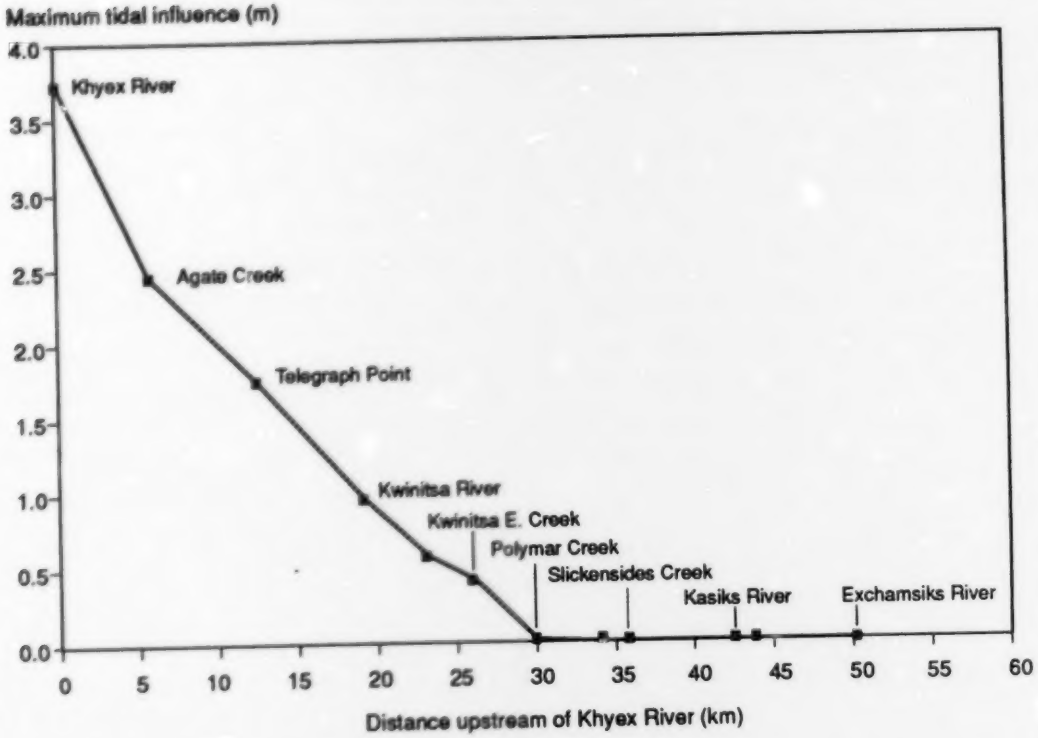

FIGURE 2.6. Tidal influence along the Skeena River in the North Coast Forest District.

2.3.3 Soils and stratigraphy

The soils of the Skeena floodplain are typical alluvial deposits formed by the successive deposition of gravels, sands, and silts. The stratified layers are most often discontinuous, thus forming a heterogeneous medium. The surface layer is generally a well-structured, porous silt overbank deposit. Below this layer can be found several layers of much denser silts and sands of low hydraulic conductivity.

The depth of surface organic material (LFH) is minimal (0-3 cm) on these rich sites due to active fauna and rapid decomposition. Decomposing roots are the main source of buried organic material. The organic matter content in the top 10 cm of mineral soil averages about 3%, with a range of 1.5-7.0%. A representative diagram of the soil characteristics of these floodplains, illustrating changes in texture, bulk density, porosity and saturated hydraulic conductivity (Ksat) with depth, is presented in Figure 2.7.

2.3.4 Soil climate

Average daily soil temperatures between May and October, under a dense alder canopy, varied between 12 and 17°C. The removal of the alder canopy caused these soil temperatures to increase substantially (Table 2.1).

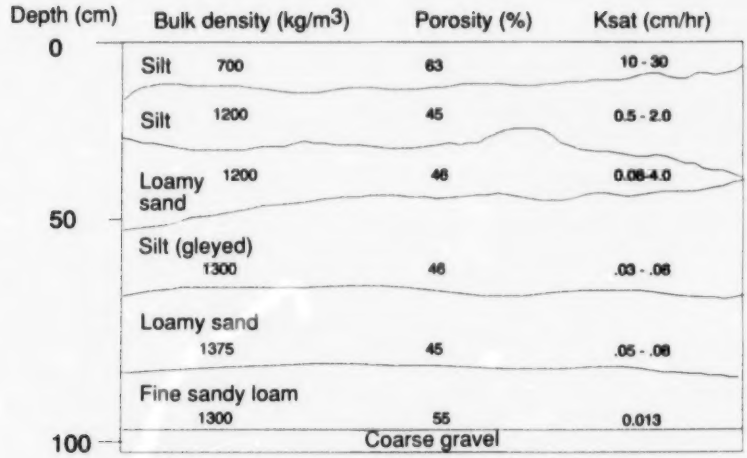

FIGURE 2.7. Typical profile of the Skeena River alluvial deposits.

TABLE 2.1. Average soil temperature range at the study site (May - Oct. 1987)

Vegetation cover	Soil depth			
	5cm	10cm	15cm	20cm
Complete alder canopy	12-17°C	12-16°C	12-15°C	14-15°C
Bare soil	10-34°C	12-27°C	14-23°C	15-18°C

Because of the wet climate, these soils remain to field capacity[3] for much of the growing season. During 1988, soils remained moist throughout the growing season (soil moisture tension constantly below 0.5 bars). In 1987, soils remained moist for all but 2 weeks in early August, when bare soils dried out (1 bar). Apart from the flooded periods, these soil climatic conditions are favourable for active microbial activity and, consequently, rapid nutrient cycling.

During the winter months the soils do not usually freeze because they are well insulated by a 1-3 m snowpack. Soil temperatures near the soil surface remain close to 1°C from November through to April. These winter conditions are less favourable for microbial activity, and nutrient cycling is slowed down during this period.

2.3.5 Groundwater regime

Describing the hydrological regime of the floodplain involved the study of both the water movement below the ground (i.e., groundwater) and the water movement above the ground (i.e., flooding). On the floodplain, water table fluctuations are predominantly driven by the seasonal fluctuations of the Skeena River. As the river rises, water infiltrates from the river into the alluvial deposits. The degree of response of the water table, whether rising or falling, depends on the

3 **Field capacity** is not an exact value. It is generally considered to be the moisture condition which stabilizes in a soil after it has been thoroughly wetted by rain or irrigation.

distance from the mainstem or large back channels, the duration of the floodwave in the river, the rate at which the river rises or falls, and the resistance of the alluvial strata to water movement.

The height of the river itself is controlled, for the most part, by the regional climate. Thus, high flows are a result of the higher elevation snowmelt and long-duration rainstorms that occur simultaneously over most of the watershed. Since the water table responds to the height of the Skeena River, it too depends directly on the regional climate. The local climatic conditions confined to the lower floodplain area, such as localized snowmelt or rainfall, generally have very little influence on the level of the regional water table.

The main characteristic of both the groundwater and river hydrographs is the annual occurrence of two large peaks (Figure 2.8). Because of the size and geographic distribution of the watershed, these coastal floodplains are subject to a combination of interior and coastal climate. The first peak (spring) results from high elevation snowmelt occurring simultaneously over the entire basin. The second peak (autumn) occurs as a result of the large rainstorms that travel through the entire watershed.

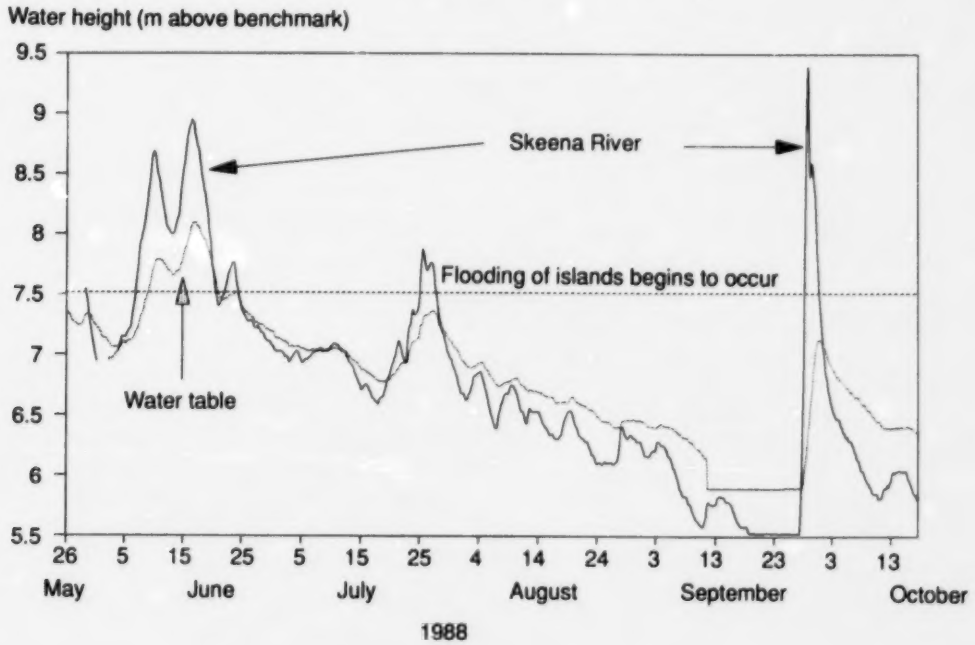

FIGURE 2.8. Groundwater and river hydrographs for 1988.

Figure 2.8 compares the fluctuations in height of the Skeena River to those of the water table. Of note is how quickly the groundwater responds to the river fluctuations. This groundwater response becomes slower and the amplitude lessens with increasing distance from the river. Consequently, high groundwater levels can only result from sustained high levels of the river; and a long duration high flow will cause the water table to rise higher than a very short duration extreme flow. This process is illustrated using the 1988 data (Figure 2.8). The sustained high flows of the spring are able to drive the water table to the surface, flooding many low-lying areas (schematically presented in Figure 2.9A & B). Although the autumn flows are often higher than the spring flows, they are of shorter duration and thus the water table usually does not reach the surface in the autumn. This autumn rise in the water table may not be high enough to cause flooding, but it can impede drainage.

Saturated flow in the soil can also occur from the surface downward. This happens in response to localized events such as rapid snowmelt and intense rainfall. A perched water table forms because of the higher density and low hydraulic conductivity of some of the near-surface sand and silt layers (Figure 2.9C). Under these conditions, ponding can occur, even though the regional water table may be 3-4 m below the surface (Figure 2.9C). We observed substantial lateral movement of water through small root channels and worm tunnels. This flow of water also occurs at the interface of the low density surface silts and the much higher density silts, loams and sands (Figure 2.7).

In addition to a rising water table and poor drainage, flooding occurs from river water overtopping the banks (Figure 2.9D). On many sites, this overbank flooding occurs several times a year, causing extensive inundation. The duration of inundation depends on the local relief (i.e, whether the surface waters can drain laterally or whether they pond on the site). This process and its consequences are discussed in Chapter 4.

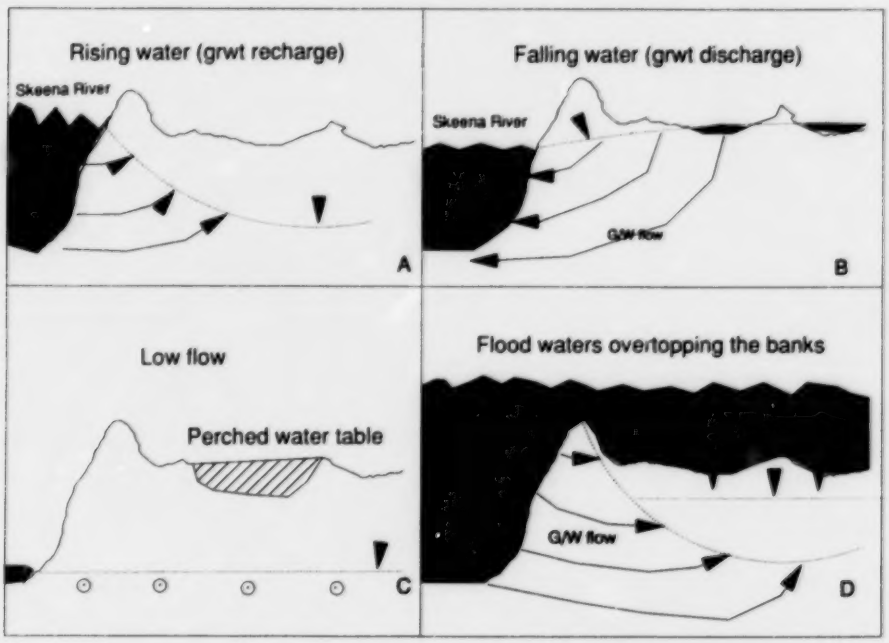

FIGURE 2.9. Relationship between river height and groundwater flow along the lower Skeena River floodplain (obtained from flow net analysis). Arrows represent direction of groundwater flow; the dotted line and reversed triangle represent the water table.

3 FLOODPLAIN STABILITY AND ISLAND LONGEVITY

D. L. Hogan and J. W. Schwab

3.1 Introduction

Prudent planning for silvicultural investment on a floodplain requires that several fundamental questions on erosion and flooding be resolved. One of these questions is: "Will a particular area be eroded away before planted trees become merchantable?" This chapter deals with floodplain stability and longevity.

Initial estimates of longevity can be determined by partitioning the floodplain into zones of relative stability. The floodplain is a composite landform consisting of many unique features. These range from flat valley floors and terraces which are stable over forest management time scales, to active channel zones which are highly unstable over similar time periods. Islands are part of the channel zone, so further evaluation is necessary if their stability and value to forest management is to be realized. Islands undergo a natural cycle of events, including a sequence of building, modification and, ultimately, destruction (Figure 3.1). This cycle must be considered while island longevity is being evaluated.

In addition to natural causes of floodplain modification, the influence of man's activities on sediment supply to the floodplain and, in particular, to the channel, is another complicating factor. Any activities in the watershed causing increased sediment supply may lead to channel aggradation, widening, and increased reach instability (Schumm 1977). Studies have shown that some islands become more unstable after logging (e.g., Church 1983; Rollerson[4]). The simple fact that a particular channel island has been stable for time periods of sufficient length to produce a mature timber stand does not guarantee its future stability.

No quantitative information pertaining to floodplain and channel island stability has previously been available for the lower Skeena River. The Kalum and North Coast Forest Districts recognized the possible implications of island instability and longevity as a limiting factor to producing harvestable stands of timber. A recent management plan for the area states that "it must be noted that viewing these sites [lower Skeena islands] as a high priority investment option is based on the assumption that they will remain stable."[5]

3.1.1 Study objectives

The objectives of this study were:

1. to document the history of island development (formation and erosion) of the lower Skeena River over the past 40 years;
2. to evaluate the longevity of islands by determining the rate of channel movement; and,
3. to develop a classification scheme which identifies relatively stable areas suitable for silvicultural investment.

3.1.2 Environmental setting

The lower Skeena River study area extends from Telegraph Point to Terrace. This area is an expansive depositional zone and forms a floodplain extending approximately 75 km in length and 2.5 km in average width. The lower Skeena floodplain is characterized by numerous divided

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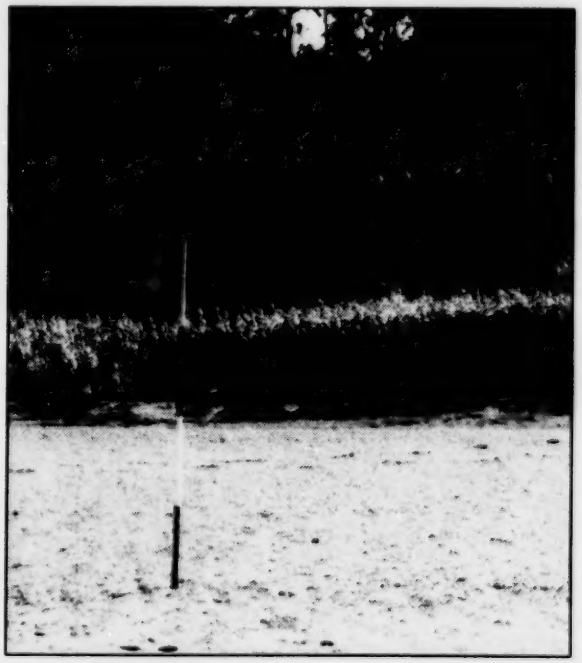
4 Rollerson, T.P. 1984. Channel stability in natural and logged river systems (northern Vancouver Island). MacMillan Bloedel Limited, Woodlands Services Division. Unpublished manuscript. 20 p.

5 Thomson, T.M. & Associates. 1985. Lower Skeena River forest management plan. B.C. Min. For., Victoria, B.C. Unpublished report, p. 20.

Islands build by sediment deposition as flood flows subside . . .

Islands expand as accretion of finer textured sediment continues . . .

Islands trimmed, sculpted and destroyed during floods . . .



Islands are re-built downstream and the sequence begins over.

FIGURE 3.1. Typical sequence of island development by erosion and deposition along the lower Skeena River.

channels, backwaters, and swampy areas resulting from shifting islands and gravel bars. Islands range in size up to 300 ha. Historically, these islands have undergone substantial change. This part of the Skeena River is the most unstable section of the entire river; upstream reaches are controlled by bedrock to a much greater extent.

The lower Skeena River has been separated into 10 reaches (Figure 3.2).[6] The morphology of each reach is described in Table 3.1. In general, the reaches are characterized by alternating straight channels, with frequent irregularly spaced islands, and sections with sinuous channel pattern and continuously overlapping islands with two or more flow branches. Gravel bars are prevalent, typically located in mid- or side channels and at the major confluences. Log jams are frequent in most of the sinuous channels and they obstruct flow into the smaller channel branches. Sloughs are common in several reaches (e.g., reaches 4 and 8) and have been influenced by the construction of road and rail routes.

3.2. Study Approach and Methods

3.2.1 Study approach

The steps followed to evaluate floodplain stability are shown in Figure 3.3. The final delineation of stable sites for silvicutural investment was based largely on island longevity. This was determined by systematic review and mapping of the channel position from chronological sequences of air photographs. The areas of land eroded and deposited were then calculated and used to determine the rate and direction of floodplain movement. These were classified into zones and plotted on maps.

3.2.2 Methods

The methods used to complete each task listed in Figure 3.3 are discussed in this section. The historical stability of the floodplain is based on changes evident on air photographs taken over the last 40 years. Five air photograph series were used to produce accurate and undistorted planimetric maps at a scale of 1:12 000.[7] The details are given in Table 3.2.

The following features were mapped from all air photographs:

- bank position, both sides of channel
- water line, both islands (and gravel bars when visible, as a function of flow)
- vegetation class on islands (including mature forest, immature forest and shrub classes)
- control points

The maps were then used to compare the relative position of channel banks and islands over time. Superimposition of one map over the next (different time period) was a straightforward procedure because the maps were produced to a common scale with the same control points. This procedure led to the production of four overlay maps drawn to the same scale as the planimetric maps (1:12 000). These overlay maps show areas of apparent deposition between successive maps (sediment surface present at the later date but absent at the earlier date), and of apparent erosion (island present at earlier date but absent at the later one). The vegetated land area was used as the discriminating criterion so that inaccurate measures of deposition or erosion were not made as a result of different streamflow stages between time periods. An example of channel changes over two of the four time periods is given in Figure 3.4.

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6 A river reach is defined by Kellerhals et al., (1976) as having homogeneous channel pattern, valley flat-channel relations, and discharge.

7 Pacific International Mapping Corporation of Victoria, B.C. prepared the photogrammetric maps using a Wild B-8(s) stereo plotter and controlled bridging to ensure horizontal control between successive photo models.

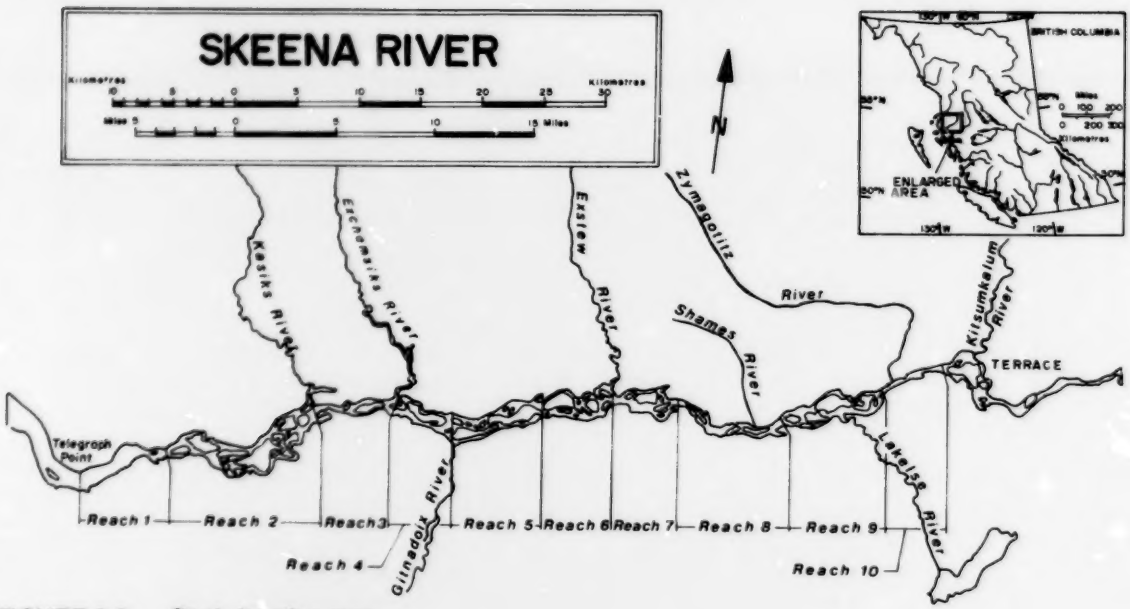

FIGURE 3.2. Study location map.

TABLE 3.1. Summarized morphology of the channel reaches shown in Figure 3.2

Reach	Location	Valley flat extent[a]	Valley wall confinement[b]	Channel pattern[c]	Channel islands[d]
1	Telegraph Point to Kwinitsa R.	Continuous	Partial	Sinuous, Split	Frequent irregular, Split
2	Kwinitsa to Selma Island	Fragmentary	Confined	Sinuous	Frequent irregular
3	Selma Island to Kasiks R.	Continuous	Partial	Sinuous, Irregular	Frequent irregular
4	Kasiks R. to Exchamsiks R.	Continuous	Partial	Straight, Sinuous	Split, Anastomosing
5	Exchamsiks R. to Gitnadoix R.	Nearly Continuous	Partial	Straight	Split
6	Gitnadoix R. to Hudson Bay Flats	Fragmentary	Continuous	Straight	Anastomosing
7	Hudson Bay Flats to 5 km east of Estew R.	Fragmentary	Continuous	Sinuous	Split, Anastomosing
8	5 km east of Estew R. to Shames Creek	Fragmentary	Continuous	Sinuous	Split
9	Shames Creek to Amsbury	Fragmentary	Continuous	Sinuous	Anastomosing
10	Amsbury to Zymagotitz	Fragmentary	Continuous	Straight	Frequent irregular

a Valley flat refers to the relatively flat surfaces on the valley floor subject to flooding.
b Confinement refers to extent the river is deflected by the valley wall.
c Channel pattern: sinuous pattern has slight curvature of channel; irregular channel has no repeatable pattern.
d Channel islands: frequent irregular refers to frequently overlapping islands; split refers to continuously overlapping islands; anastomosing refers to continuously overlapping islands with two or more flow branches.

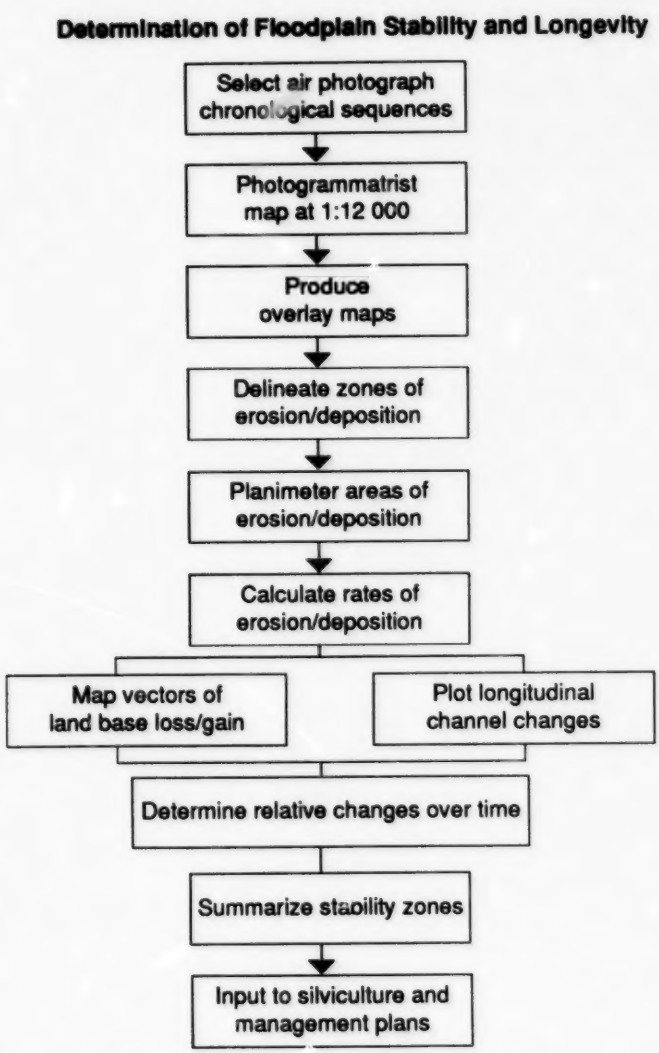
Determination of Floodplain Stability and Longevity
Select air photograph chronological sequences
Photogrammatrist map at 1:12 000
Produce overlay maps
Delineate zones of erosion/deposition
Planimeter areas of erosion/deposition
Calculate rates of erosion/deposition
Map vectors of land base loss/gain
Plot longitudinal channel changes
Determine relative changes over time
Summarize stability zones
Input to silviculture and management plans

FIGURE 3.3. Study procedures.

TABLE 3.2. Air photographs used to map channel changes in the lower Skeena River

Year of photo sequence	Approximate scale	Photo reference numbers
1947	1:31 680	BC441 - BC447
1963-64	1:31 680	BC5078, 5084, 5111
1975	1:20 000	BC7782,7813,7728
1980	1:10 000	BC80024-80036
1987	1:10 000	BCC594-595

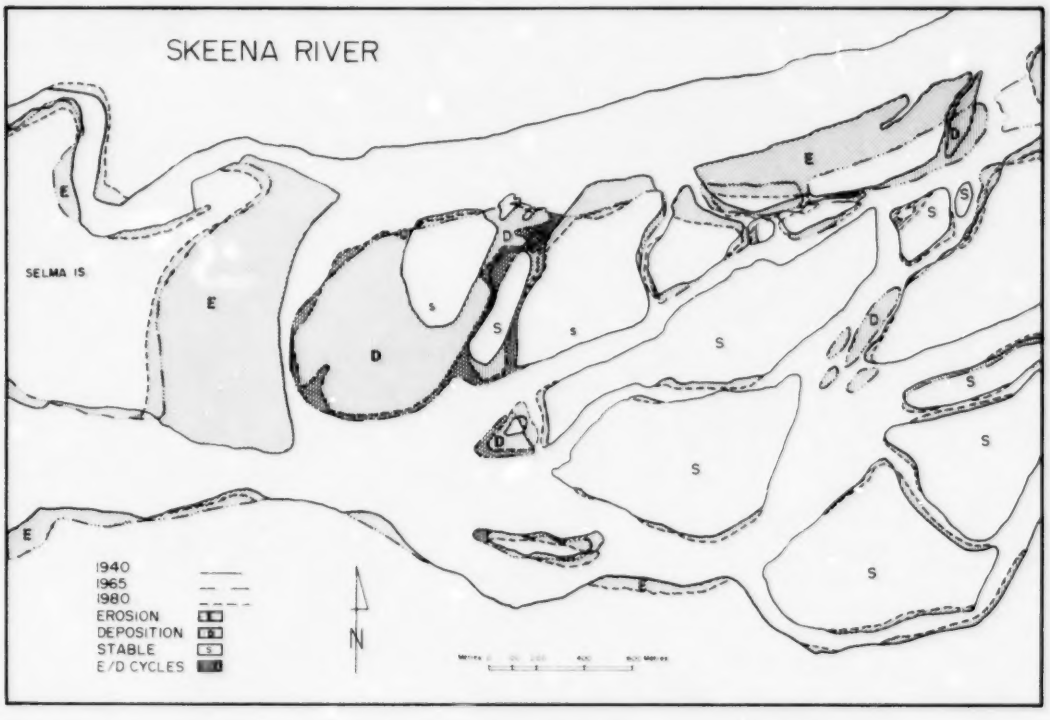

FIGURE 3.4. Example of overlay maps developed to determine erosion and deposition rates over time.

The next step was to planimeter all of the areas delineated as deposition and erosion zones. The entire length of the study area was separated into 1-km segments and the areas of deposition and erosion within each 1-km segment and for all four time periods (1947-1963, 1963-1975, 1975-1980, and 1980-1987) were planimetered. The area values were plotted on the overlay maps and used to calculate annual rates of change.

A series of maps were then drawn with vectors to show the actual location and rate of erosion and deposition along the channel. The map vectors were drawn to scale representing rates ranging from less than 0.125 ha/yr to over 2.5 ha/yr. The vectors were colour-coded to identify the four time periods.

The purpose of the map vectors was to summarize the erosion and deposition rates over the four time periods. That is, by viewing the colour-coded vectors for all time periods combined, one could see an integrated summary of changes over time. This was based on a classification of five zone types which are detailed in Table 3.3. The summary erosion/deposition maps were reduced from the original scale of 1:12 000 and re-drawn at 1:20 000.

Finally, a system was developed to summarize island stability. The classification used is given in Table 3.4. Summary stability maps were drawn at a scale of 1:20 000.

TABLE 3.3. Description of summary erosion and deposition zones

Zone	Description
I	Areas without measurable erosion or deposition over the 40-year study period (1947-1986).
II	Areas of continual deposition over the study period: 0.75 ha/yr in total and usually consisting of many small zones (<0.125 ha/yr) and no large single zones.
III	Areas of little erosion and/or little deposition. Erosion or deposition not exceeding 0.75 ha/yr in total. Consisting of many small zones (<0.125 ha/yr) and no large single zones.
IV	Areas of erosion and deposition; erosion and deposition exceeding 0.75 ha/yr.
V	Large areas of erosion. Erosion exceeding 0.75 ha/yr and usually consisting of many large areas.

TABLE 3.4. Description of island stability classes

Zone	Description
A	Islands appearing to be stable or growing. Suitable for silvicultural investment. Possibly incorporating stability zones I, II, and III. Possibly including open water (back channels).
B	Both erosion and deposition since 1947, or transition between A and C.[a] Primarily Zone IV, but possibly including I, II, III, open water and back channels.
C	Areas of erosion or transport (open water) or areas historically stable but threatened by possible future erosion. Sites not suitable for silvicultural investment. Primarily zones V and open water, but possibly including stability zones I, III, IV, and, rarely, II.

a Make silvicultural investments only after careful on-site investigation.

3.3. Results and Discussion

The floodplain stability analysis led to the production of a series of maps. The results include the following:

1. Planimetrically correct maps of floodplain features for five dates.[8]
2. Erosion and deposition rate, direction, and location maps for four time periods.[8]
3. Erosion and deposition summary maps.[9] These five maps integrate the four time periods and are based on a five-class system (Table 3.3). Selected map sections are presented in Figure 3.5.
4. The floodplain stability has been summarized from the calculated erosion and deposition rates. Selected map sections are presented in Figure 3.6.[9]

8 Maps (scale of 1:12 000) are on file, Forest Sciences Section, Smithers, B.C.
9 Maps (scale of 1:20 000) are available from the Kalum and North Coast District offices or the Forest Sciences Section, Smithers, B.C.

These four sources of information can be used differently by various user groups. Results included in 1, 2, and 3 above may be used by researchers interested in calculating sediment transport and trying to understand river processes better. Silviculturists working at the operational or field level will probably use the information included in 2 and 3. Planners will probably be most interested in information included in 4.

Many factors contribute to channel changes. Along the lower Skeena River, the factors that appear most important are:

- river flows and flood history
- sediment sources
- morphological features
- nature of vegetation (stabilizing influence) on islands and floodplains
- human activities, such as logging and road/rail construction.

River flows are important to erosion over a wide range of conditions. Erosion occurs on a continuous, seasonal, or intermittent basis at different locations along the watershed. In areas where the channel is confined by the valley wall and the channel bends, erosion can occur continuously over the entire year. These areas often experience areal erosion rates in excess of 2 ha/yr, and linear losses of tens of metres. Above-normal rates of erosion and deposition also occur during the seasonal floods. Although we do not have exact dates, it appears that very high erosion rates were experienced during the 1948 flood. Intermittent changes appear related to other factors, such as the integrity of log jams. For instance, it seems that large, extensive log jams tend to protect the channel banks from erosion and in some cases promote deposition. Once the jams break down, however, they no longer protect the banks, and erosion rates may become much greater.

Sediment sources are very important to erosion and deposition rates. Major sediment sources include tributaries and eroding upstream islands. The erosion and deposition along the river are summarized for all time periods in Figure 3.7. Also included in this figure is the location of all major tributaries and the degree of channel confinement. In general, there is a major net aggradation of the Skeena River downstream of most tributaries. The level of importance of each tributary depends on several characteristics, but the nature and quantity of sediment introduced at the confluence is of primary importance. These depend on conditions within the watershed, including soil erosion related to land-use practices. Overall, Figure 3.7 shows that the entire study area is a "net deposition" zone. The high levels of erosion, within the overall depositional zone, represent a normal process of floodplain development.

Specific morphological features were also used to identify stability zones. Valley wall confinement influences erosion and deposition rates (Figure 3.7). The aggradational zones are particularly large in areas associated with wide floodplains. These split and branching channels experience various levels of lateral activity (see Figure 3.5). The narrow channel sections are typically sediment transport zones. That is, zones that are confined by the valley walls or other man-made structures (e.g., highway and railway embankments) are characterized by straight or sinuous, single-thread channels where sediment is transferred through the reach so that deposition is rare, or limited to short time periods. Lateral activity is restricted in these areas.

The shape and position of a floodplain site with respect to the river flow direction is also an important consideration. Island areas are eroded at much faster rates when they are positioned across the flow direction and along the outside of channel bends. These areas represent higher risk locations for silviculture investment.

In addition to protecting channel banks against erosion, log jams often develop at the inlet of channel branches. Once the jams are established, flows seem to reduce in the back channel, even during floods. As result, these channels experience higher depositional rates and may eventually be closed off completely to the main channel flow.

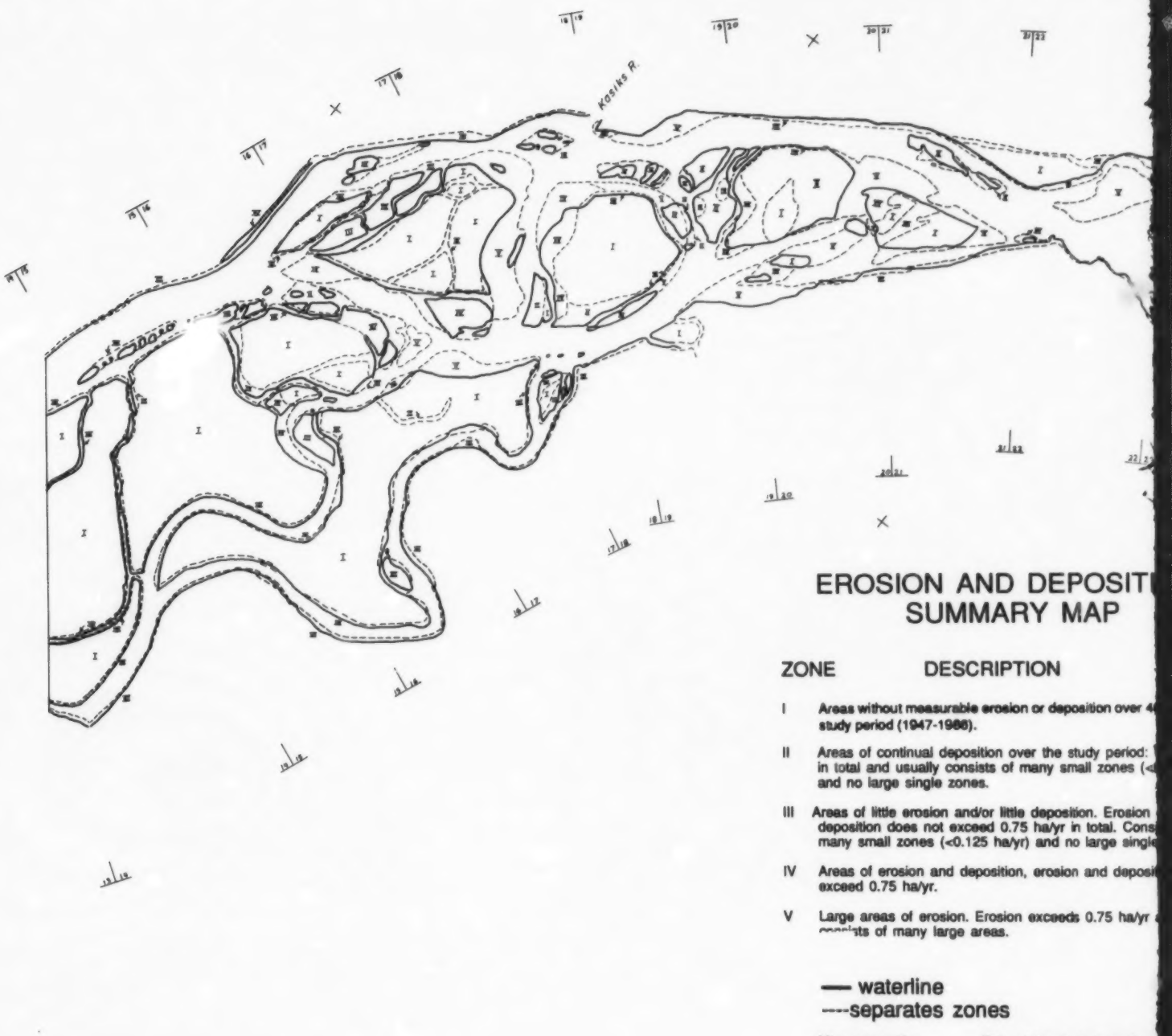
SKEENA RI
KASIKS R.
EROSION AND DEPOSIT
SUMMARY MAP
ZONE
DESCRIPTION
I Areas without measurable erosion or deposition over 4
study period (1947-1986).
II Areas of continual deposition over the study period:
in total and usually consists of many small zones (<
and no large single zones.
III Areas of little erosion and/or little deposition. Erosion
deposition does not exceed 0.75 ha/yr in total. Cons
many small zones (<0.125 ha/yr) and no large singl
IV Areas of erosion and deposition, erosion and deposi
exceed 0.75 ha/yr.
V Large areas of erosion. Erosion exceeds 0.75 ha/yr
consists of many large areas.
— waterline
----separates zones
Map preparation:
May,1989
Date of latest photography
June 26,1987 (BCC594)
B.C.Forest Service, Forest Sciences Section, Smithers

FIGURE 3.5. Example of erosion and deposition summary maps.

ENA RIVER

ON AND DEPOSITION SUMMARY MAP

DESCRIPTION

easurable erosion or deposition over 40 year
7-1986).

al deposition over the study period: 0.75 ha/yr
ally consists of many small zones (<0.125 ha/yr)
gle zones.

sion and/or little deposition. Erosion or
not exceed 0.75 ha/yr in total. Consists of
s (<0.125 ha/yr) and no large single zones.

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rosion. Erosion exceeds 0.75 ha/yr and usually
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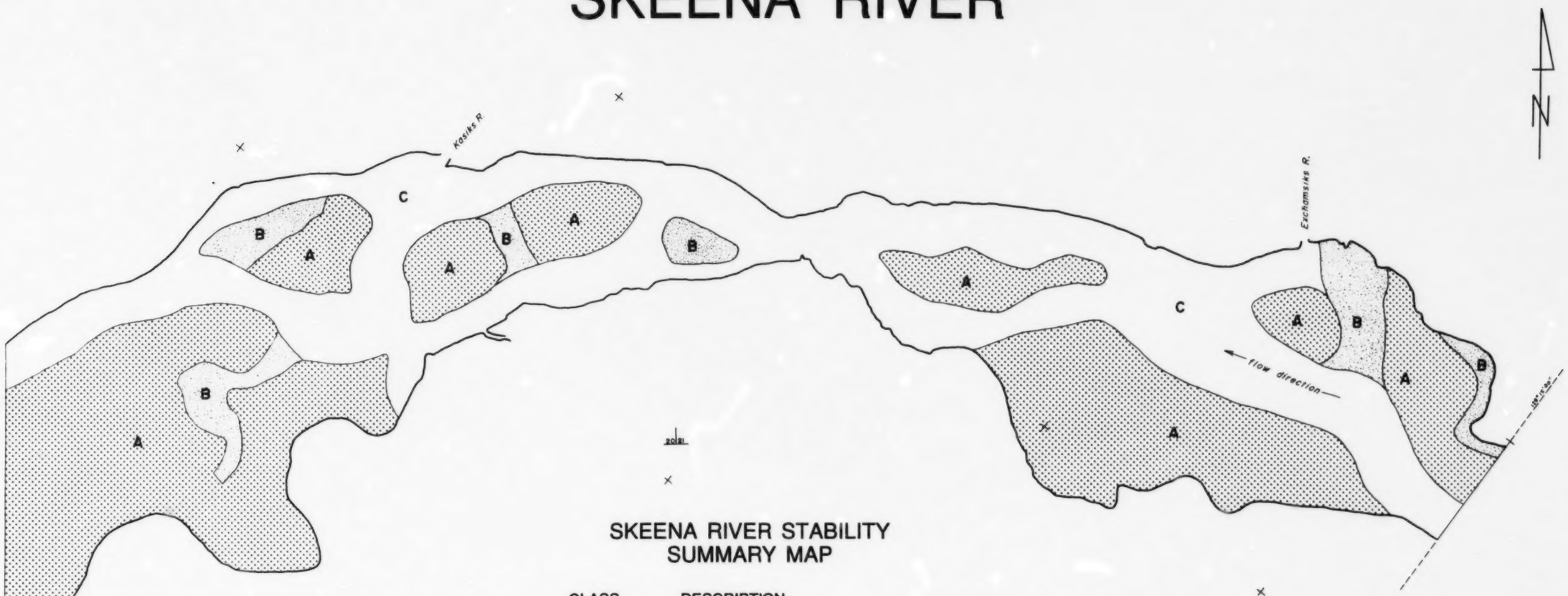
Date of latest photography used:
June 28,1987 (BCC594)
e, Forest Sciences Section, Smithers B.C.

SKEENA RIVER



SKEENA RIVER STABILITY SUMMARY MAP

CLASS	DESCRIPTION
A	Islands appears stable or growing. Suitable for silvicultural investment. May incorporate zones I,II,III. May include open water.
B	Both erosion and deposition since 1947, or transition between A and C. Make silviculture investments only after careful on-site investigation. Primarily zone IV, but can include I,II,III, water and back channels.
C	Areas of erosion or transport (open water) or areas of historically stable sites but threatened by possible future erosion. Sites not suitable for silviculture investment. Primarily zone V and open water, but may include I, III, IV and rarely II.

——waterline

Map preparation: May,1989
Date of latest photography used: June 28,1987 (BCC594)
B.C.Forest Service, Forest Sciences Section, Smithers B.C.

FIGURE 3.6. Example of floodplain stability maps.

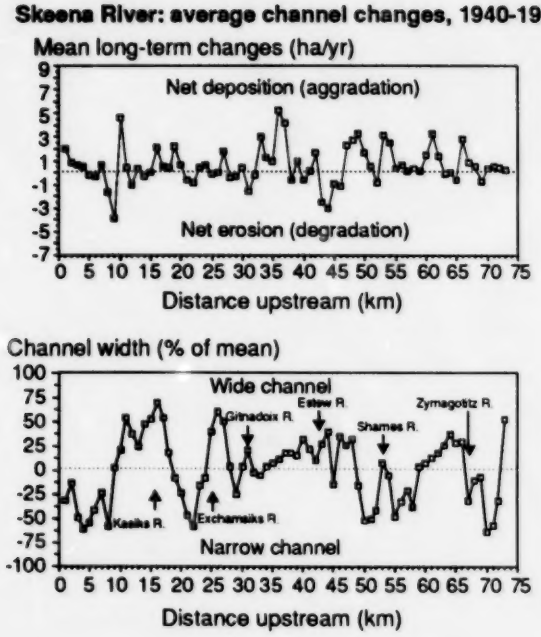


FIGURE 3.7. Longitudinal changes in net erosion and deposition along the lower Skeena River.

The role of vegetation in stabilizing floodplain sites varies depending on the site. First, successional vegetation on exposed gravel bars does appear to reduce erosion and promote further deposition of fine-textured sediment. These are seen along point bars and the downstream tails of islands. However, once the islands have developed to a certain elevation the stabilizing role of vegetation is diminished. There are many examples along the river where active erosion is taking place below the root network. In most cases, the coarser sediment (mainly gravels and cobbles) that forms the base of the finer-textured sediment used by roots are eroded, leaving a concave lower bank profile. The overlying sediment often reaches 3 m in thickness and usually has a vertical bank profile. As the bank is progressively undercut, the overlying block of sediment eventually collapses into the river (Figure 3.8). Vegetation has little, if any, stabilizing influence on the islands in these situations. However, the trees that topple into the river can reduce erosion downstream, as discussed above, for some length of time.

Man's activities include alterations in sediment supply and can directly influence channels by the placement of road and rail routes. The re-alignment of roads and railways has directed the mainstem flow towards islands and floodplain areas at certain places along the Skeena River. These areas have subsequently experienced increased erosion rates. On the other hand, there are also sites where side channels are cut off from the main river and have since experienced increased depositional rates.

These factors affecting erosion and deposition were identified as a result of the evaluation of chronological sequences of air photographs. The information was incorporated into our assessment of floodplain stability. Further work is currently under way to quantify the relative importance of these and other factors, which will help improve our ability to identify areas suitable for silvicultural investment.

Evaluating floodplain stability also has a strong economic incentive. Given the relatively low cost to prepare the interpretive island stability maps, weighted against silviculture costs, this type of mapping should be conducted for all large floodplain areas under active forest management. Once suitable areas have been identified, the flooding characteristics of the stable land should be identified. This aspect is considered in the next chapter.

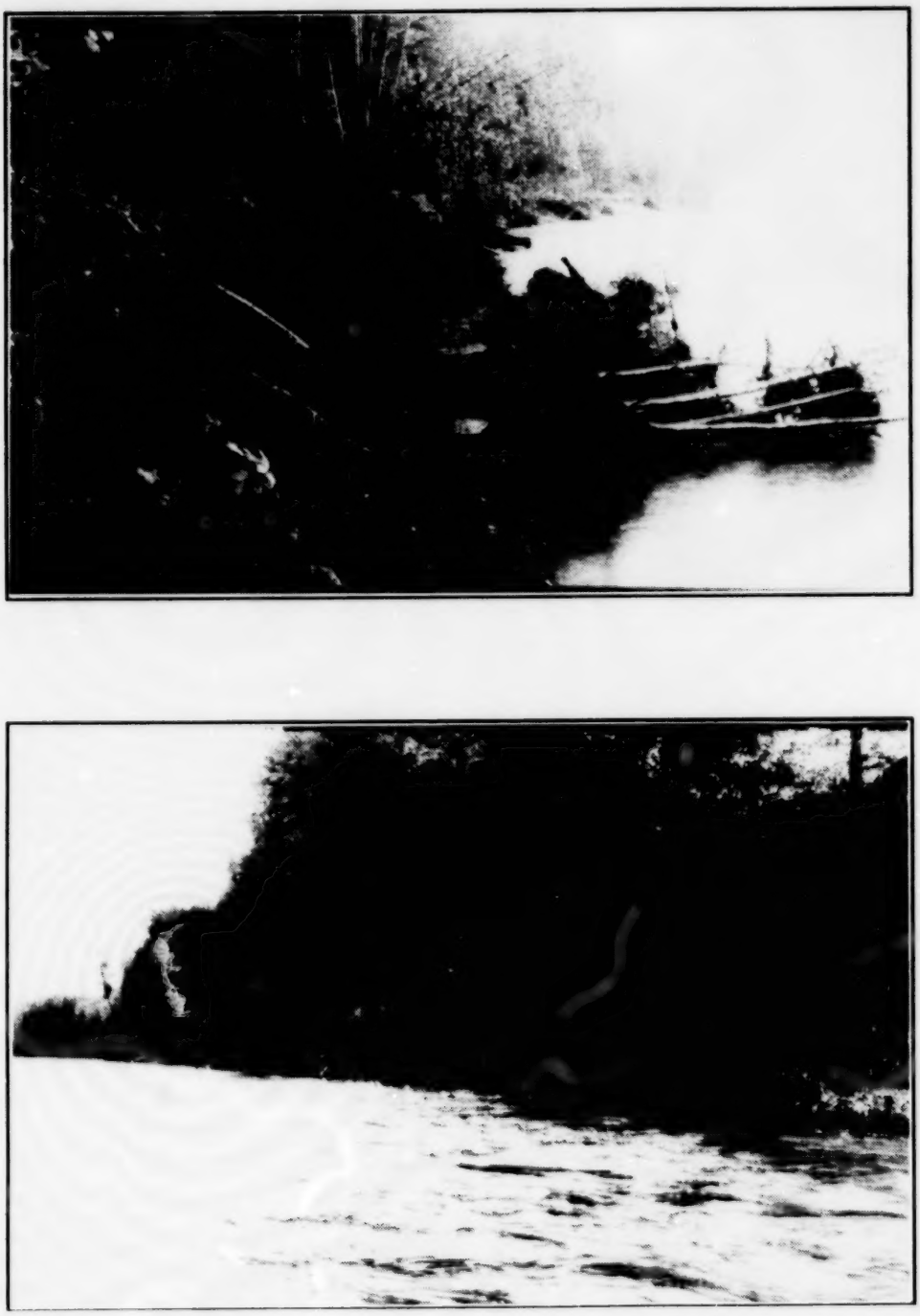


FIGURE 3.8. Island erosion below rooting depth.

4 FLOOD HAZARD CLASSIFICATION FOR SILVICULTURE

P.G. Beaudry and D.L. Hogan

4.1 Introduction

On certain alluvial islands of the lower Skeena River, silviculturists have noted a large variability in the success of establishment and growth of Sitka spruce. The most obvious growth problems are associated with those seedlings located in the depressions and lower areas of the floodplain (Figure 4.1). Much of this variability has been attributed to the extensive flooding that occurs annually (Figure 4.2). The literature also provides evidence that prolonged flooding can be detrimental to the survival and growth of young Sitka spruce seedlings (Coutts and Philipson 1978; Philipson and Coutts 1978; Coutts 1981; Grossnickle 1987).

FIGURE 4.1. Spring floods on the Skeena Islands.

Silviculturists have identified specific questions about flooding and the regeneration of the lower Skeena floodplain, including:

- How often and how long do these sites flood?
- Is flood hazard solely a function of site elevation?
- Is there a critical elevation below which Sitka spruce cannot survive?

- Is it possible to identify the difference between a good and an unacceptable growing site?
- Can the flooding potential of a site be described and classified, and then related to the success potential of various silvicultural activities?

This study was initiated to help answer these questions. The main objectives were: 1) to describe the physical flooding processes (i.e., frequency, duration and pathways); 2) to determine the effects of flooding on the growth of Sitka spruce seedlings; and 3) to devise a classification/mapping system, based on readily available air photographs, that could highlight areas with high flooding hazards. The classification was to aim at assisting in the planning phase of the NSR (not sufficiently regenerated) rehabilitation programs by providing support for pre-harvest silvicultural prescriptions.

FIGURE 4.2. Submerged seedlings during flood.

4.2 Methods

The initial phase of this study involved describing the hydrology of the lower Skeena River and the flooding processes of the islands, including the location, frequency and duration of flooding. This information is provided in Chapter 2. From these results, we developed the first draft of a simple flood hazard classification which had five flood hazard classes. These classes were based on features identifiable on 1:10 000 scale air photographs. The flooding frequency and impacts identified in these classes ranged from "frequent flooding, impossible to grow Sitka spruce" to "rare flooding, growth of spruce is not affected by high water."

The initial classification system was field tested on a few of the islands of the lower Skeena. This field verification consisted of: 1) comparing our predicted flooding levels with the actual flooding levels over various parts of the island; and 2) determining the effects of the various levels of flooding on the growth of Sitka spruce. The final classification system is presented in the results section of this chapter.

In March 1988, we established numerous transects across the "test" islands and set stakes designed to indicate the height of maximum flood. In August 1988, we returned to the islands and recorded the height of flooding for each stake. These height-of-flood data were mapped, then compared to the initial predictions obtained using the initial flood hazard classification. The field check identified certain weaknesses in the classification system and revisions were made accordingly. A more detailed description of the methodology is available in Beaudry (1989a).

For the first field check, we chose Skeena Island 002 in the North Coast Forest District. This island was chosen because of its recent logging and silvicultural history. The island was logged, broadcast burned, bladed and scarified in 1982, planted with Sitka spruce plugs in 1983, manually brushed in 1984, and sprayed with the herbicide Roundup® (Vision®) in 1986. A survey done in the spring of 1988 revealed that the success of the plantation varied widely from one area to another. In some areas, the growth of the seedlings was excellent; in others the seedlings did not survive.

From initial visual observations, this variation in the establishment and growth of the seedlings seemed to be closely correlated to ground elevation, which of course greatly affects depth and duration of flooding. To understand these relationships better, three transects were established across the island to measure ground elevation and seedling height. On the transects, we used a survey level to measure total height of the seedlings and the relative ground elevation at the location of the seedlings. From 75 to 125 paired measurements of seedling height and ground elevation were made along each of the three transects (Figure 4.3). To determine how flooding depth actually affects the growth of spruce seedlings, we plotted the height of the seedlings versus the ground elevation data for each of the transects, and performed a linear regression on each set of data.

FIGURE 4.3. Location of seedling height - ground elevation transects.

4.3 Results and Discussion

The flood indicator stakes were read in July 1988, about 1 month after spring peak flows. Those readings established that flooding was widespread over the entire island and that maximum flooding depths reached 2 m. The spring peak flows of 1988 were about average (Environment Canada 1989), which suggests that inundation is a regular process on these islands.

In general, where the flooding was deep (i.e., greater than 1.2 m) the growth of Sitka spruce was poor. In several cases, however, growth of Sitka spruce was excellent even though flooding depths were greater than 1.2 m. A significant relationship was obtained between the elevation of the ground and the height of the spruce seedlings. Figure 4.4 gives the ground elevation profile of transect #1 on the bottom section and the height of each of the spruce seedlings measured along that profile on the top. This figure shows well that small gains or losses in elevation can have a substantial effect on the growth of spruce. We used several types of regression equations to describe this relationship; these included linear, exponential, logarithmic and power curve. The linear regression was selected, as it provided the best correlations (Figures 4.5A-C). The relationships are statistically significant at the 99% probability level for all three transects. Ground elevation explained 53%, 56%, and 62% of the variation in tree height, for transects 1, 2, and 3, respectively.

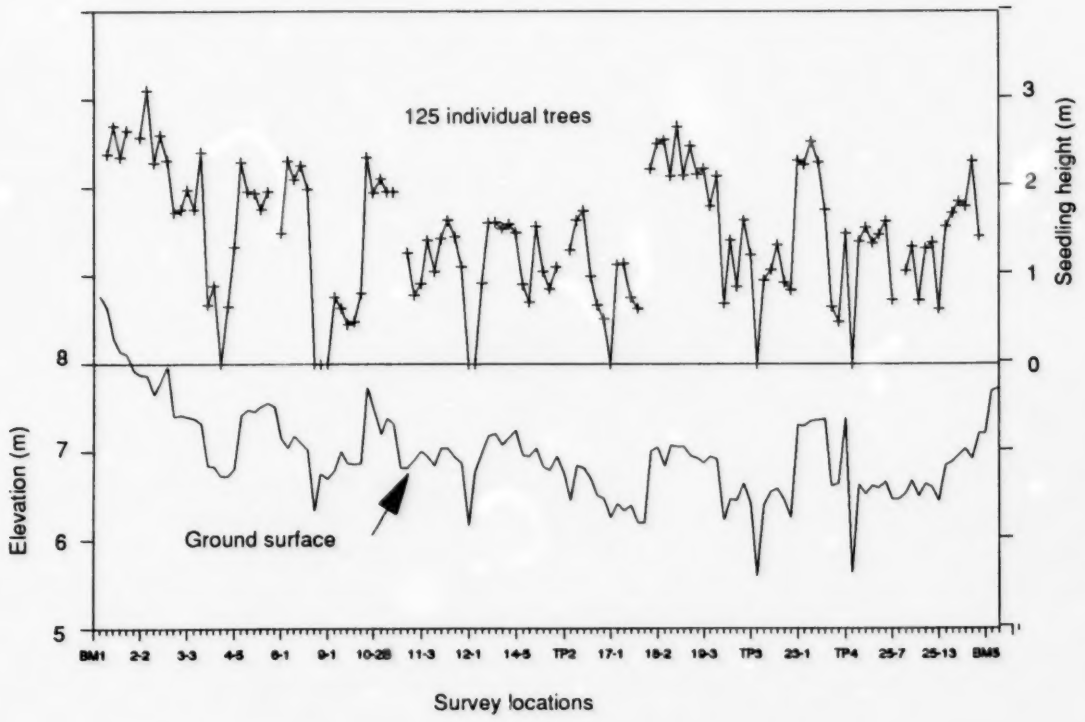
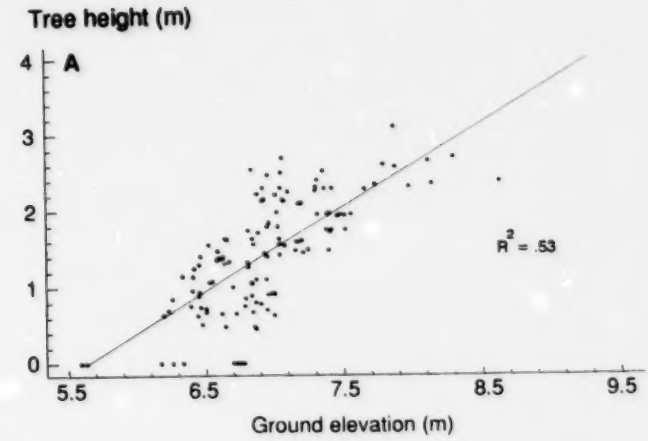
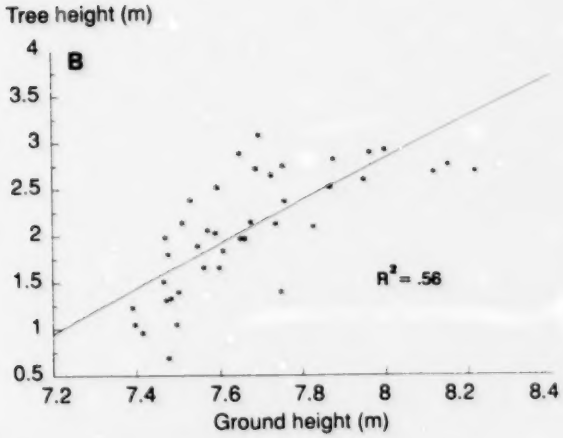


FIGURE 4.4. Seedling height - ground elevation transects.





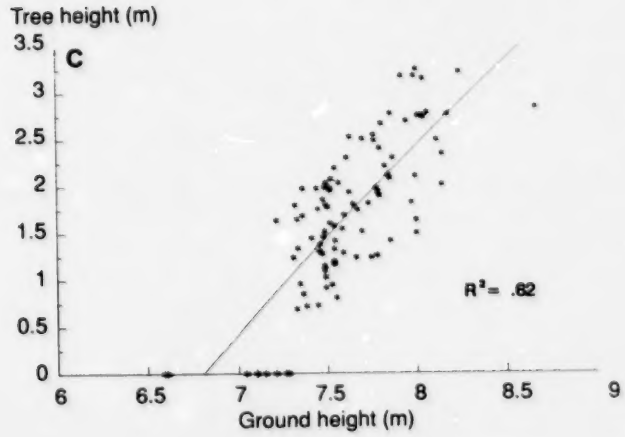


FIGURE 4.5. Linear regression of tree height over ground elevation. A) Transect #1, B) Transect #2, C) Transect #3.

These results confirm those obtained with the flood stakes. Ground elevation does not explain all of the variation in the growth of Sitka spruce. Our observations suggest that the variation in growth is best explained by a combination of both depth and duration of flooding. Other factors that no doubt might have an influence include: poor planting, soil conditions, genetic variation, browsing, disease, and pests.

We combined the river height data and the data on the elevation of various landscapes to obtain a measure of duration of flooding (Figure 4.6). Those data show, for example, that the river height can be higher than the height of the lowlands for 20-30 days a year. Thus, seedlings located in these lowlands may have their roots in saturated soils for 20-30 days, or more, per year.

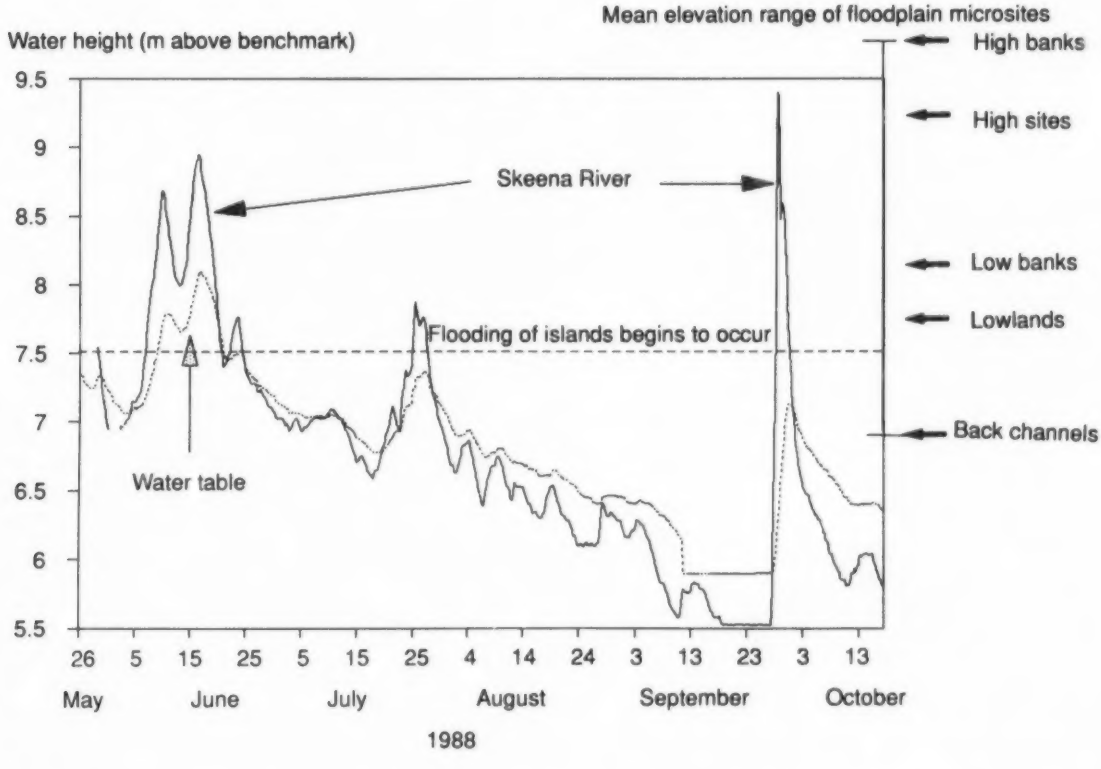


FIGURE 4.6. Groundwater and river hydrographs relative to elevation of various landscapes for 1988.

In addition to the topographic elevations for each flood hazard class, we also needed the description of geomorphic features that affect duration of flooding. The descriptions of those geomorphic features were obtained from the study of both the flooding and draining processes. The most important flooding process is the overtopping of the banks (Figure 4.7A). Other processes that have consequences to spruce growth are the rising of the water table and impeded drainage (i.e., ponding, see Chapter 2). A thorough understanding of how the sites flood and subsequently drain is essential for the prediction and operational mapping of flood hazard. In summary, the various processes operate as follows:

- As the river rises, initial flooding occurs by overtopping low areas of the streambank. The river water flowing in through these low areas either follows old abandoned channels or spreads out over the lowlands.
- As the river continues to rise, the higher banks get overtopped and most of the floodplain can become covered in water. The maximum stage height of the river determines the maximum depth of flooding. The longer the river remains high, the longer the seedlings are submerged at maximum depth. The most dramatic effects on young Sitka spruce seedlings happen as a result of extended periods of high flows in June, which is only a few weeks after the seedlings are planted in April-May.
- With a rise in the river there is a corresponding rise in the water table. However, the water table rises more slowly than the river and the delay gets larger with distance from the main channel or large back channels (Figure 4.7A). The recession of the water table is also delayed relative to the fall of the river, with the recession being the slowest at the furthest point inland from a large back channel or main channel (see Chapter 2, Figure 2.9).
- As the river drops, so does the depth of flooding, until the river level reaches the height of the riverbank or natural or man-caused levee. At this point, if there are no dips or depressions in the bank or levee, the water becomes trapped inside the levee so the floodplain remains flooded.
- If the high flows have been sustained long enough, the water table rises close to the surface and drainage of any trapped water is impeded. Thus, the duration of flooding within certain areas of an island can be substantially longer than the duration of river peak flows (Figure 4.7B).

The understanding of these processes leads to the definition of two important landscape features in relation to duration of flooding (features which are easily identified on air photographs): 1) the low areas that are **"open"** at one end, allowing free drainage of flooded waters (e.g., abandoned back channels); and 2) the low areas that are **"closed"** to direct drainage back to the river. These two landscape features can be at the same elevation, but because of their "open" or "closed" nature, the duration of flooding can be substantially different. Consequently, the growth of Sitka spruce would be much better on an "open" type of landscape than on a "closed" type at the same elevation.

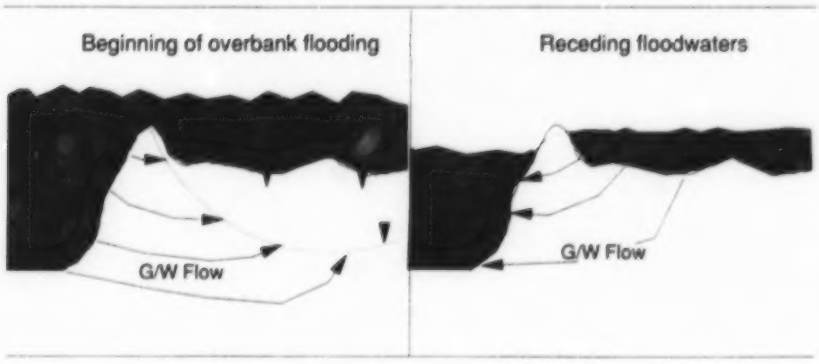


FIGURE 4.7. Overbank flooding and recession.

4.3.1 The flood hazard classification system

The natural routing of floodwaters into and out of a mainland or island floodplain can often be identified on air photographs. The residence time of the floodwaters can be deduced from the topography of the site and the flooding principles described in the previous section.

The process of classification begins with the identification, on 1:10 000 air photographs, of topographical and morphological features that affect flood height and duration. The classification ranges from Class I, where flooding does not affect spruce growth, to Class V, where establishment and growth of spruce is impossible.

The system should be used to stratify areas for silvicultural prescriptions before rehabilitation work is started. Field surveys often cannot identify the geomorphic features that serve as routes of entry and exit of flood waters because of the dense brush and the small elevational changes involved. The processes and features are most often best identified from the air photos. Areas identified as high flood hazard should be avoided or planted with more flood-tolerant species such as cottonwood.

Soil surveys done using an Oakfield soil sampler did not show any obvious differences in soil characteristics between classes. We suspect that this is the case because the difference in flooding duration between classes is generally not long enough to cause changes to soil properties. Vegetation may serve as a useful indicator to classify sites for flood hazard. This topic area, however, needs further study. Both old-growth and second-growth forest vegetation would need to be correlated to depth, duration and frequency of flooding.

The main features used to map the flood hazard classes on the photos are:

- linear depressions that are "open" to the main channel.
- depressions that are "closed" to the main channel.
- distance from the river flow (mainstem or back channel).
- hummocks and elevated areas.

The definition and identification characteristics of the five classes are as follows:

Class V

Frequency	-	Floods at a wide range of flows, several times a year for extended periods.
Duration	-	Total number of flooded days a year can exceed 40.
Implications	-	No hope for establishment or growth of Sitka spruce seedlings. Should be classed as non-commercial (NCC).
Topography	-	Located in the lowest elevations at the bottom of "closed" or "open" depressions.

Class IV

Frequency	-	Floods several times a year with mean annual high flows.
Duration	-	Total of 20-25 days per year, longer for higher peak flows.
Implications	-	Growth rate of spruce seedlings is reduced; establishment is often not successful; cottonwood may be preferred.
Topography	-	Located immediately above class V or in moderate depressions that are "closed" to free drainage. Although these sites are at the same elevation as Class III, the "closed" characteristic increases duration of flooding and consequently affects growth and establishment of planted seedlings.

Class III

Frequency	-	Floods several times a year with mean annual high flows.
Duration	-	Total of 10-15 days per year, longer for higher peak flows. Note the shorter duration differentiates it from Class IV.
Implications	-	Growth of Sitka spruce is less than ideal, but can be acceptable. Survival can vary, depending on extent of flooding the year the seedlings are planted.
Topography	-	Same elevation as Class IV, but sites are not confined. The most important characteristic is the "open" configuration.

Class II

Frequency	-	Floods annually, usually once in the spring and once in the fall to a depth of 30-90 cm.
Duration	-	Short; several hours to 1-2 days.
Implications	-	Growth is good.
Topography	-	High ground located between Class III and I. On air photos it is difficult to distinguish between Classes I and II. However, because both are safe classes, this has little consequence.

Class I

Frequency	-	Flooded not more than once a year.
Duration	-	If flooded at all, duration is short–a few hours to half a day.
Implications	-	The short duration flooding has no detrimental effect to tree growth.
Topography	-	High ground.

We applied the classification to the tree height - ground elevation data collected on the three transects of Island 002 by grouping the observations into the five classes (Figures 4.8A-C). The data fit best into the classes for transects 1 and 3. Because transect #2 was located parallel to the riverbank (Figure 4.3), it did not encounter as many elevational changes and thus only represents a limited number of classes.

Maximum growth rates are achieved in Class I. In Class II, no obvious relationship exists between seedling height and ground elevation. These trees are on relatively high sites where flooding has little effect. Their growth depends more on factors other than flooding. The trees in Class III and IV are located within the same elevation. However, trees in Class III are taller because they are located in "open", better-drained landforms. Better drainage implies less time submerged and, consequently, better growth. In Class V, the planted trees did not survive.

The system is useful as an initial silvicultural planning tool to identify relatively large areas that are prone to flooding. Future refinements to the system and the addition of information correlating vegetation characteristics to the flood hazard classes may eventually make the system more precise.

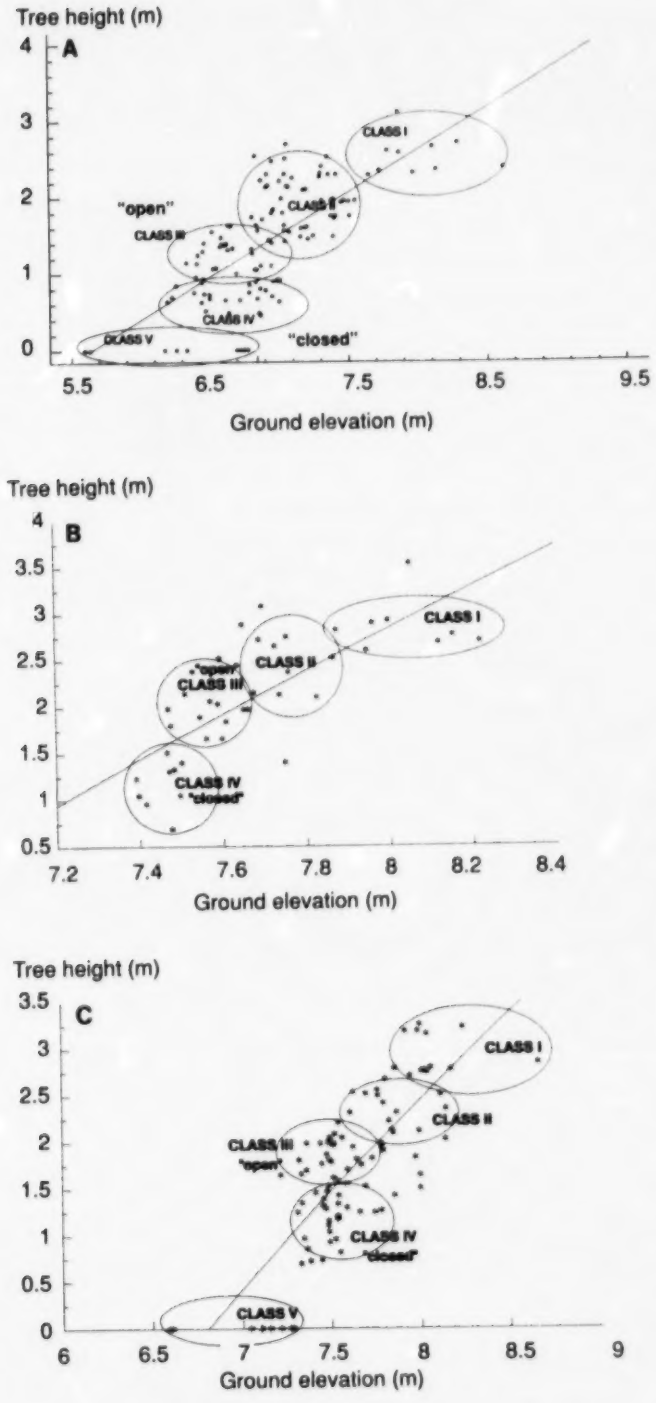


FIGURE 4.8. Flood hazard classification applied to A) Transect #1, B) Transect #2, C) Transect #3.

5 THE FATE OF FORESTRY HERBICIDES ON THE SKEENA FLOODPLAIN

P.G. Beaudry

5.1 Introduction

What will be the fate of herbicides applied to the Skeena floodplains? What happens to that portion of the herbicide that does not reach, or is not used up by, its target? Will the herbicide move off the site with rain or snowmelt water? Will the herbicide leach into groundwater? These questions are the type of questions being asked by concerned members of the public and various resource agencies.

In the previous chapters we described various processes and properties of the floodplain environment. These included climate, soils, hydrology and geomorphology. In this chapter the information will be applied to an operational problem: predicting the fate of forestry herbicides on the Skeena floodplain.

Much is known about the physical and chemical properties of the various herbicides registered for forestry use in British Columbia. By combining this knowledge with some of the information provided in this report on the properties of the floodplain environment, a forester can make a reasonable prediction about the behaviour of a specific herbicide (Figure 5.1). The physical and chemical properties of various herbicides used in British Columbia (i.e., glyphosate, 2,4-D, hexazinone and triclopyr) are summarized in various operational publications such as FRDA Memo No. 74 (Beaudry 1989) and "A Quick Guide to Pesticides" (B.C. Ministry of Forests and Lands 1987).

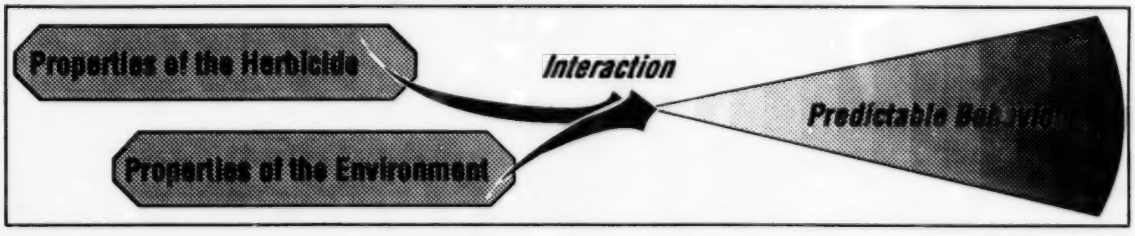


FIGURE 5.1. Herbicide - environment interactions.

5.2 Properties of the Skeena Floodplains that Affect Fate of Herbicides

5.2.1 Soils

Texture, organic matter

The important soil characteristics of these floodplain sites, as they affect the fate of herbicides, are: 1) the fine texture of the overbank deposits (silts and clays); and 2) the presence of 2-7% organic matter incorporated into the surface layers. These characteristics are important because it is the silts, clays and organic matter that provide the adsorption sites for herbicide molecules. The more adsorption sites there are in the soil, the greater will be the capacity of the soil to immobilize the herbicide molecules. This reduces the potential for vertical or lateral leaching of herbicides into groundwater or into protected water bodies.

For example, because of its strong adsorption characteristics, the herbicide glyphosate would certainly be immobilized upon contact with the alluvial soils of the lower Skeena. However, the greater soil mobility of 2,4-D (acid) and triclopyr may allow these two herbicides to leach vertically several centimetres into the soil, if the herbicide reaches the soil surface.

Although flooding and high water tables occur seasonally on these sites, timing of the application of the herbicide and the high organic matter content present in the soils should minimize off-site movement and deep-leaching associated with groundwater recession. Because of its high mobility in soils, hexazinone is not recommended for use on coastal alluvial soils.

Climate

The soil climate data (see Chapter 2) suggest that during non-flooded periods of the growing season, the temperature and moisture regime of the soil is favourable for microbial activity. Thus, during the growing season, microbial degradation will be an effective way of dissipating herbicides from the soil. However, during the winter, herbicides present in the soil may degrade very slowly because of the unfavourable winter soil conditions for microbial degradation. Thus, herbicide applications in late summer or early fall may not have the opportunity to be degraded much before the onset of winter, and consequently might be present in the soil during spring runoff and high flows. This situation may result in some leaching of soil-mobile herbicides or movement associated with surface erosion during runoff.

As an example of the effects of soil conditions on herbicide longevity, Ghassemi (1981) reports the half-life of triclopyr (active ingredient of the herbicide Garlon®) to be between 79 and 156 days for soils at 15°C, and less than 50 days for soils at 25-35°C. The Dow Chemical Company (1983) reports the half-life of triclopyr as being only 10 days. However, this is for ideal soil conditions, that is, silty clay loam at 35°C and soil moisture at field capacity. The half-life is increased to 46 days under the same conditions if the texture is a loam. Thus, a familiarity with soil conditions is essential for a forester to predict properly the fate of a particular herbicide.

5.2.2 Site

Although regular flooding occurs on these sites, the flooding is seasonal and quite predictable. This predictability allows foresters to plan any herbicide application to avoid the periods when the soils are very wet or when flooding or ponding occurs. The worst periods, environmentally, for the application of herbicides (especially the more soil-mobile ones, e.g. 2,4-D and triclopyr) would be early in the spring before spring floods or late in the summer before the fall floods. Safe periods (i.e., "windows") are identified in Figure 5.2 as late July to early September. During those periods, the water table (which is driven by the height of the Skeena River) drops to depths greater than 2 m below the soil surface (Figure 5.2). Since leaching of 2,4-D or triclopyr would be confined to the top 30 cm in this type of alluvial soil, the chances of reaching the water table are minimal if the herbicide is applied at the appropriate time. Because of its strong soil-binding properties, glyphosate would leach much less. Thus, the application of the herbicides during the safe periods would avoid potential problems such as mobilization in surface waters as a result of groundwater rise or overbank flooding.

Slope/erosion

Under some specific circumstances, herbicides attached to soil particles may move off-site during erosional processes. Because of the low topography, surface erosion is generally not a problem on the vegetated areas of the Skeena floodplains. However, indiscriminate logging and yarding activities across any of the numerous back channels that are interlaced throughout the floodplain could be a source of surface erosion. These back channels are very important to the fisheries resource of the Skeena River. Skid trails that lead across these back channels could be a potential source of surface erosion during the heavy fall rains or rapid spring snowmelt. If the surface erosion follows a recent herbicide application, it could become a source of entry of the

herbicide into the aquatic environment. Another route of entry associated with erosion may be through erosional processes of the upstream side of an island as described in Chapter 3. These erosional processes underlie the need for keeping adequate buffer strips and Pesticide Free Zones (PFZ) around all back channels and along the edge of the main channel.

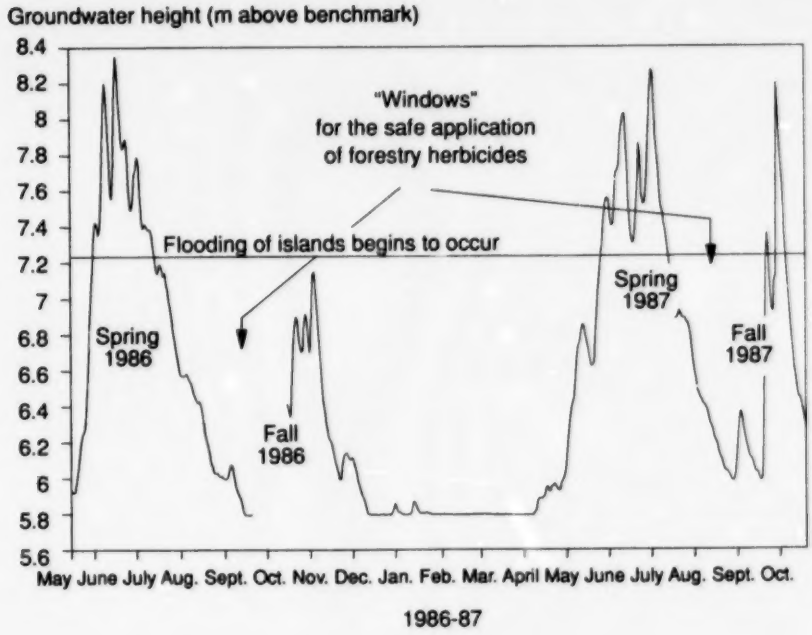


FIGURE 5.2. "Windows" for application of herbicides to avoid off-site movement.

Climate

The lower Skeena floodplain experiences a large amount of rainfall, especially in the fall and early winter (see Chapter 2). However, even this abundant rainfall will not promote vertical or horizontal leaching of glyphosate, the most widely used herbicide in vegetation management on coastal floodplains of British Columbia. The absence of significant slope, the fine texture of the surface layers of the soil, the presence of adequate organic matter and the strong soil adsorption characteristic of glyphosate are the principal reasons leaching would not be a problem. If the glyphosate is applied properly between mid-July and early September, when the water table is between 1 and 3 m below the soil surface, possibilities of contaminating the water table are nil. Although mid-summer storms do occur, they are generally not long enough or of wide enough distribution to cause large rises in the Skeena River, and this ultimately affects the height of the water table.

The rainfall regime on the lower Skeena floodplains is such that is usually keeps the soil moist throughout the growing season. This provides good conditions for soil microbial activity, which ensures rapid dissipation of the herbicide from the soil.

5.3 Discussion

Predicting the fate of a herbicide in the environment is best achieved by understanding how the properties of the chemical interact with the properties of the environment. This chapter has provided an example of how to interpret the environmental information provided in Chapter 2 and how to choose the most appropriate herbicide and best time of application to minimize undesired environmental impacts. In summary, our recommendations for applying herbicides on the Skeena floodplain are as follows:

1. Because of the high rainfall regime and the regular flooding episodes, choose a herbicide that has strong soil adsorption properties (e.g., glyphosate).
2. Maintain adequate buffer strips around all back channels. These back channels (even the small ones) can be extremely important habitat for fisheries.
3. To avoid the leaching of the herbicides into the water table and the off-site movement with surface erosion, apply all herbicides during the period between mid-July and early September.

6 REFERENCES

B.C. Hydro. 1983. Route engineering assessment of the Skeena - Rupert high voltage transmission line. Transmission Projects Division, Rep. No. Tp 1041, pp. 4.1-5.23.

Beaudry, P.G. 1989a. Hydrology of the Skeena River floodplain II: Flood Hazard Classification for Silviculture. *In* Watershed '89. Conf. on the Stewardship of Soil, Air, and Water Resources, March 21-23, 1989. Juneau, Alaska. U.S. Dep. Agric. For. Serv., Alaska Region R10-MB-77.

_____. 1989b. The Fate of herbicides in the forest environment. For. Can.-B.C. Min. For. FRDA Memo No. 74, May 1989.

B.C. Ministry of Forests and Lands. 1987. A quick guide to pesticide use and regulation in B.C. forest management. Field Handb.

Coutts, M.P. 1981. Effects of waterlogging on water relations of actively-growing and dormant Sitka spruce seedlings. Ann. Bot. 47:747-753.

Coutts, M.P. and J.J. Philipson. 1978. Tolerance of tree roots to waterlogging. Survival of Sitka spruce and lodgepole pine. New Phytol. 80:63-69.

Church, M. 1983. Patterns of instability in a wandering gravel bed channel. Spec. Publ. Int. Ass. Sediment, Vol. 6:169-180.

Church, M., Miles, M., and Rood, K. 1986. Sediment transfer along the MacKenzie River. A feasibility study. Environ. Can., Sediment Supply Rep. IWD-WNR(NWT)-WRB-SS-87-1.

Dow Chemical Company. 1983. Environmental and toxicology profile of Garlon herbicides. Tech. Data Sheet No. 137-1639-83. The Dow Chemical Company, Agric. Products Dep., Midland, Mich.

Environment Canada. 1989. Historical streamflow summary, British Columbia. Inland Waters Directorate, Water Resources Branch, Water Survey of Canada, Ottawa, Ont.

Freeze, R.A. and J.A. Cherry. 1979. Groundwater. Prentice Hall, Inc., Englewood Cliffs, N.J. 604 p.

Ghassemi, M. 1981. Environmental fates and impacts of major forest use pesticides. U.S. Environ. Protection Agency, Washington, D.C.; EPA Contract No. 68-02-3174, Work Assignment Nos. 13, 14 and 62.

Grossnickle, S.C. 1987. Influence of flooding and soil temperature on water relations and morphological development of cold-stored black spruce and white spruce seedlings. Can. J. For. Res. 17:821-828.

Hoos, L.M. 1976. The Skeena River estuary, status of environmental knowledge to 1975. Report on the Estuary Working Group, Dep. Environ., Regional Board, Pac. Region, Environ. Can. Spec. Estuary Series No. 3, Vancouver, B.C. 418 p.

Kellerhals, R., Church, M., and Bray, D.I. 1976. Classification and analysis of river processes. Hydraulics Division, Am. Soc. Civil Engineers, Vol. 102, No. HY7, pp. 813-829.

Philipson, J.J. and M.P. Coutts. 1978. The tolerance of tree roots to waterlogging III. Oxygen transport in lodgepole pine and Sitka spruce roots of primary structure. New Phytol. 80:341-349.

Pojar, J. 1988. Biogeoclimatic and ecoregion units of the Prince Rupert Forest Region (2 maps). 1:50 000. B.C. Min. For., Research Branch, Victoria, B.C.

Roemer, H.L., J. Pojar, and K.R. Joy. 1988. Protected old-growth forests in coastal British Columbia. Natural Areas J. 8(3):146-159.

Schumm, S.A. 1977. The fluvial system. John Wiley & Sons Inc., New York, N.Y. 338 p.